

MONITORING PLAN

Defense Coastal/Estuarine
Research Program 2 (DCERP2)

SERDP Project RC-2245

MAY 2013

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RTI International

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Acronyms and Abbreviations

°C	degrees Celsius
µm	micrometer
µmol L ⁻¹	micromoles per liter
AE	Aquatic/Estuarine (Module)
AEMP	Aquatic/Estuarine Monitoring Program
ARIMA	Autoregressive Integrated Moving Average (model)
AVP	Autonomous Vertical Profiler
BMA	benthic microalgae
CB	Coastal Barrier (Module)
CC	Climate Change (Module)
CCFHR	Center for Coastal Fisheries and Habitat Research
CDOM	chromophoric dissolved organic matter
CH ₄	methane
chl <i>a</i>	chlorophyll <i>a</i>
CHN	carbon, hydrogen, and nitrogen
cm	centimeter
cm s ⁻¹	centimeters per second
CO ₂	carbon dioxide
CO-OPS	Center for Operational Oceanographic Products and Services
CORS	Continuously Operating Reference Stations
CW	Coastal Wetlands (Module)
CWMP	Coastal Wetlands Monitoring Program
DC	dissolved carbon
DCERP	Defense Coastal/Estuarine Research Program
DCERP1	first cycle of DCERP
DCERP2	second cycle of DCERP
DEM	Digital Elevation Model
DIC	dissolved inorganic carbon
DIMS	Data and Information Management System
DIN	dissolved inorganic nitrogen
DIP	dissolved inorganic phosphorus
DMSO	dimethyl sulfoxide
DO	dissolved oxygen
DOC	dissolved organic carbon
DoD	U.S. Department of Defense
DON	dissolved organic nitrogen

EDD	Electronic Data Delivery
ESM	Estuarine Simulation Model
ft	feet, foot
GIS	geographical information systems
GPS	global positioning system
ha	hectare
HPLC	high-performance liquid chromatography
Hz	hertz
ID	identification
IRGA	infrared gas analyzer
K_d	diffuse light attenuation coefficient
km hr^{-1}	kilometers per hour
kPa	kilopascal
L	liter
m	meter
m s^{-1}	meters per second
m y^{-1}	meters per year
m^2	square meters
$\text{m}^3 \text{ y}^{-1}$	cubic meters per year
MARDIS	Monitoring and Research Data and Information System
mg/L	milligrams per liter
mL	milliliter
MLW	mean low water
mm	millimeter
mm y^{-1}	millimeters per year
MSL	mean sea level
NAVD 88	North American Vertical Datum of 1988
NAVFAC	Naval Facilities Engineering
NGS	National Geodetic Survey
NH_4^+	ammonium
nm	nanometer
NO_2^-	nitrite
$\text{NO}_2^- + \text{NO}_3^-$	nitrate + nitrite
NO_3^-	nitrate
NOAA	National Oceanic and Atmospheric Administration
NRE	New River Estuary
NTU	Nephelometric Turbidity Units
OMS	Optical Monitoring System
OPUS	Online Positioning User Service

PAR	photosynthetically active radiation
pCO ₂	partial pressure of carbon dioxide
PI	Principal Investigator
PO ₄ ⁻³	orthophosphate
POC	particulate organic carbon
PON	particulate organic nitrogen
PPR	primary production
ppt	parts per thousand
QA	quality assurance
QC	quality control
RCCC	Resource Conservation and Climate Change
RTK-GPS	real-time kinematic global positioning system
SCC	suspended sediment concentration
SERDP	Strategic Environmental Research and Development Program
SET	surface elevation table
SiO ₃ ⁻²	silicate
T	Terrestrial (Module)
TDN	total dissolved nitrogen
TDP	total dissolved phosphorus
TOC	total organic carbon
TN	total nitrogen
TSP	Translating Science into Practice (Module)
TSS	total suspended solids
UNC-IMS	University of North Carolina at Chapel Hill's Institute of Marine Sciences
USGS	U.S. Geological Survey
VRS GPS	virtual reference stations global positioning systems
YSI	Yellow Springs Instruments, Inc.
ZnCl ₂	zinc chloride

1.0 Background

1.1 Introduction

Critical military training and testing on lands along the nation's coastal and estuarine shorelines are increasingly placed at risk because of development pressures in surrounding areas, impairments due to other anthropogenic disturbances, and increasing requirements for compliance with environmental regulations. The U.S. Department of Defense (DoD) has established ecosystem-based management as the preferred approach for military lands (Goodman, 1996). To expand its commitment to improving military readiness while demonstrating the science behind this approach, the Strategic Environmental Research and Development Program (SERDP) has made a commitment of a minimum of 10 years to fund research and monitoring projects that support the sustainability of military training and testing in ecologically and economically important ecosystems.

To accomplish this goal, and in particular for coastal environments, SERDP launched the Defense Coastal/Estuarine Research Program (DCERP) at Marine Corps Base Camp Lejeune (MCBCL) in North Carolina (**Figure 1-1**) in 2006. As a U.S. Marine Corps installation, MCBCL has a single and exclusive mission: military preparedness. MCBCL provides an ideal platform for DCERP because it integrates coastal barrier, aquatic/estuarine, coastal wetland, and terrestrial ecosystems, all within the boundaries of DoD properties.

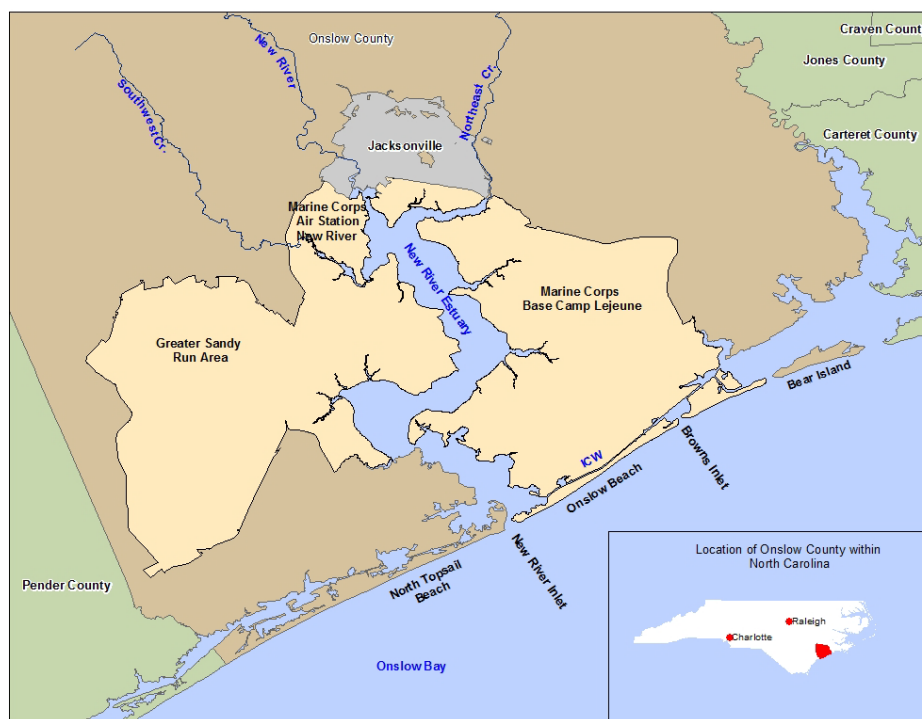


Figure 1-1. Site map of MCBCL in Onslow County, NC.

DCERP was implemented in two contract periods. The first cycle of DCERP, referred to as DCERP1, was conducted from July 2006–January 2013. The second cycle of DCERP, referred to as DCERP2, has a 3-month planning period (November 2012 to January 31, 2013) and an implementation period of 4 years and 9 months (February 1, 2013 through November 1, 2017). Since DCERP1 was implemented, the potential impacts of climate change on military training have been identified as a growing challenge to our nation's military readiness. DoD facilities in coastal/estuarine areas are at additional risk from climate

change, including changes in rising sea level and extreme weather (i.e., severe droughts, heavy rainfall events, warming temperatures, and increased magnitude of storms). In addition, installation managers need to understand the trade-offs between carbon management and other adaptive management decisions to reach installation carbon goals in a changed climate. To balance military training needs and sustainable natural resource management, installation managers need easy-to-use decision-support tools, models, and other products to assist them in making often complex management decisions; therefore, the specific objectives of DCERP2 include the following:

1. Determining how ecosystem processes (within military training environments) respond to climate change to understand the resiliency and adaptive capacity of these ecosystems
2. Building on DCERP1 findings to identify additional thresholds that can serve as indicators of tipping point conditions that could threaten sustainability of the military training mission
3. Assessing opportunities for adaptive management of estuarine, coastal, and terrestrial ecosystems to enhance carbon storage at MCBCL and other installations in similar coastal settings
4. Conveying results of scientific studies to managers and decision makers by developing clearly written products and easy-to-use decision-support tools and models hosted on a readily accessible Web-based platform.

This *DCERP2 Monitoring Plan* will serve as a guide throughout the DCERP2 implementation period to provide a summary of the monitoring programs of the Aquatic/Estuarine and the Coastal Wetlands Modules. For DCERP2, “monitoring activities” are defined as data that are needed to support research and modeling effects for three or more research projects. This Monitoring Plan is also intended to serve as a reference for documenting specific monitoring objectives, field and laboratory procedures, and data analyses methods; and for identifying research projects supported by the monitoring data, major outcomes, and deliverables. This *DCERP2 Monitoring Plan* will also discuss the ways in which monitoring efforts are communicated among the RTI DCERP Team, SERDP staff, DoD installation managers, and other interested stakeholders. We have purposely written this monitoring report to address specific details of the monitoring programs. Readers who are interested in more information about the organization of DCERP2, the history of the program, DCERP’s overarching strategy, the integration of the monitoring program with the 13 research projects, and data management and data policy details should refer to the companion document, the *DCERP2 Research Plan*.

1.2 Program Organization

RTI International is leading the DCERP2 research and monitoring effort. In this capacity, RTI has assembled a diverse team of experts, henceforth referred to as the RTI DCERP2 Team. DCERP is a collaborative effort between SERDP, the Naval Facilities Engineering (NAVFAC) and Expeditionary Warfare Center, MCBCL, and the RTI DCERP2 Team. SERDP is an environmental research and development program that is planned and carried out by DoD in full partnership with the U.S. Department of Energy and the U.S. Environmental Protection Agency. The SERDP Resource Conservation and Climate Change (RCCC) Program Manager, Dr. John Hall, and the DCERP On-site Coordinator, Dr. Susan Cohen, provide technical oversight and management of the program. Together, they ensure that tasks identified in the Statement of Work are properly performed by the DCERP Principal Investigator (PI), Dr. Patricia Cunningham of RTI. The DCERP PI is responsible for the overall scientific quality, cohesiveness, and relevance of the *DCERP2 Monitoring and Research Plans*.

In addition to the DCERP PI, the RTI DCERP2 Team includes environmental scientists from RTI, and researchers from academic institutions, governmental agencies, and private companies. The academic institutions supporting DCERP2 are Duke University in Durham, NC; North Carolina State University in Raleigh; the University of North Carolina at Chapel Hill; the University of Connecticut in Groton, CT; the Virginia Institute of Marine Science in Gloucester Point, VA; and Virginia Polytechnic Institute and

State University in Blacksburg, VA. The team also includes researchers from governmental agencies: the National Oceanic and Atmospheric Administration's (NOAA's) Center for Coastal Fisheries and Habitat Research (CCFHR) in Beaufort, NC; and the U.S. Army Corps of Engineers' Field Data Collection and Analysis Branch in Duck, NC, and Construction and Engineering Research Laboratory in Champaign, IL. Private companies supporting DCERP2 include Aquatic Analysis and Consulting, LLC, in Wilmington, NC; Geodynamics, LLC, in Pine Knoll Shores, NC; and Seahorse Coastal Consulting in Morehead City, NC.

As it was for DCERP1, the RTI DCERP2 Team, led by Dr. Cunningham, remains organized around four interconnected ecosystem modules established in DCERP1 (i.e., Aquatic/Estuarine [AE], Coastal Barrier [CB], Coastal Wetlands [CW], and Terrestrial [T]). Because climate change has a central role on ecosystem function and services, a fifth cross-cutting Climate Change (CC) Module will link the ecosystem modules to a central suite of local and regional-scale climate forcings. Finally, data and outcomes from all of our integrated research and monitoring efforts will be managed within the new Translating Science into Practice (TSP) Module, which incorporates many elements of the DCERP1 Data Management Module.

1.3 DCERP Overarching Strategy

DCERP2 is based on integrated research and monitoring activities that are structured to use measurements and develop conceptual and mechanistic models and tools that inform science-based adaptive management at MCBCL and that can be easily transferred to other DoD installations. The monitoring program is designed to document trends, but to be sufficiently adaptive to capture extremes and ecosystem threshold events and to support the Research Plan by satisfying fundamental data needs. Together, these research and monitoring activities represent an integrated continuum of ecosystem response to changing climate, with respect to carbon cycling, nutrient utilization, sediment loading, and ecosystem services and sustainability. The *DCERP2 Monitoring Plan*, which is designed to gather basic environmental data, directly supports the *DCERP2 Research Plan*. The Monitoring Plan can be adapted based on results from research projects such as changes in the frequency of sampling, spatial extent of sampling locations, or parameters to be sampled. Ultimately, the RTI DCERP2 Team will use results from the monitoring and research efforts to identify ecosystem indicators and develop associated threshold values, tools, or design models that address installation management needs. Team members will then communicate this information to MCBCL and more broadly to other DoD installations to assist in the decision-making process. Once this information is transitioned to the installation, the DoD's natural resources managers will be able to make decisions as to what type of management action should be taken and to implement appropriate physical or military operational changes. After implementing these changes, the RTI DCERP2 Team can continue monitoring (via feedback loop) to ensure that the desired management outcomes are achieved.

Conceptual models are used to illustrate the key biological processes (e.g., primary production), chemical processes (e.g., nutrient cycling), and physical processes (e.g., hydrodynamics, sedimentation) that are the driving forces of the function of the ecosystem in the absence of stressors. The conceptual models also show the key stressors that alter natural ecological processes. The RTI DCERP1 Team developed an overarching conceptual model, which the RTI DCERP2 Team has revised, that links ecosystem level processes in the aquatic/estuarine, coastal barrier, coastal wetlands, and terrestrial ecosystems as is shown in **Figure 1-2**. This overarching conceptual model highlights the interconnections among the various ecosystem modules in examining the estuarine and coastal processes that are affected by climate change and that drive carbon cycling.

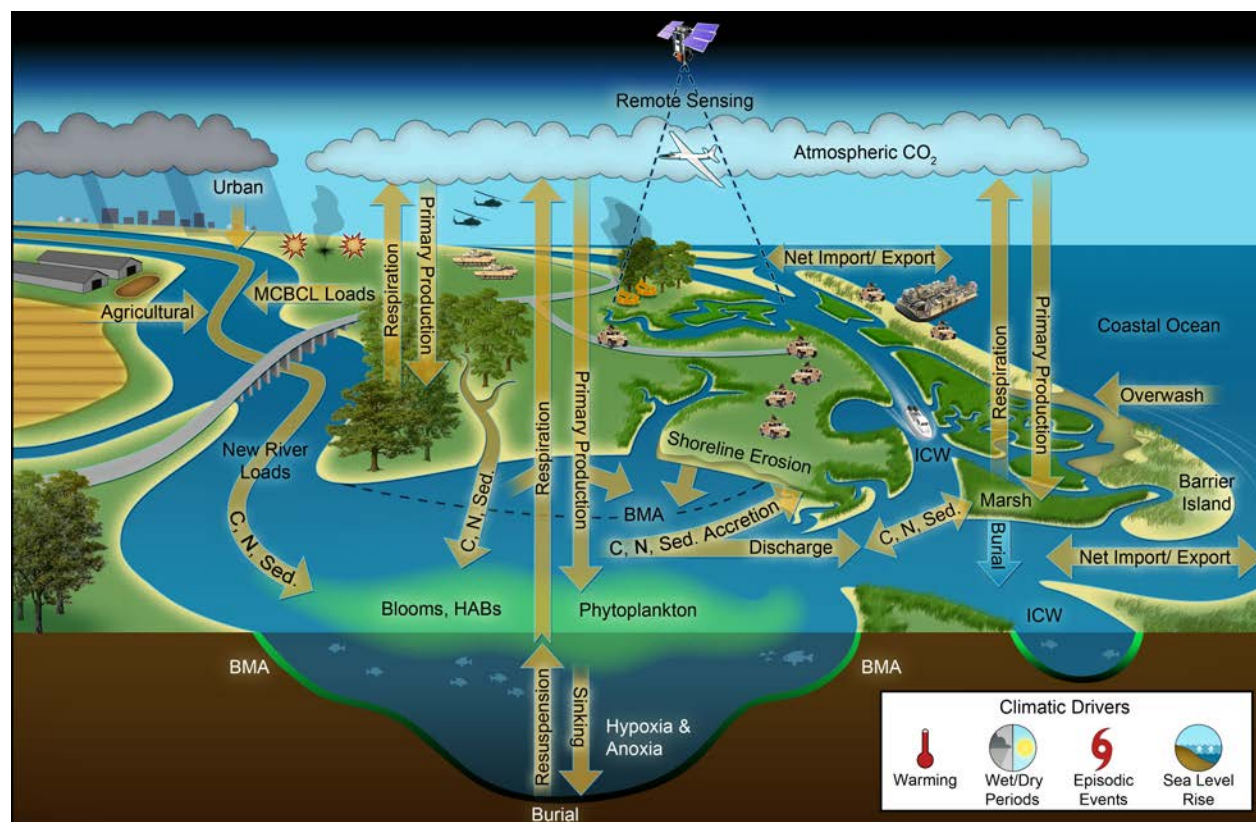


Figure 1-2. The overarching conceptual model for DCERP2.

Detailed, module-specific (i.e., Aquatic/Estuarine, Coastal Wetlands, Coastal Barrier, and Terrestrial) conceptual models were then developed that highlight individual ecosystem-level processes. These models were designed to integrate the ecological processes and stressors with a focus on DCERP2's thematic areas of climate change, carbon cycling, and translating science into practice. As new understanding of these ecosystem processes and stressors is gained during the course of DCERP2 research, the module-level conceptual models will be revised based on this new information to make these complex concepts clearer to a wider audience. In addition, the RTI DCERP2 Team created module-based roadmaps to illustrate and track all monitoring and research activities to ensure within- and among-module integration of research and data collection activities. For more information about the module-specific models and roadmaps, see the *DCERP2 Research Plan*.

1.4 DCERP2 Thematic Areas

SERDP identified three major themes to be addressed in DCERP2: climate change, the carbon cycle, and translating science into practice. These three themes span the four ecosystem modules and 13 research projects of DCERP2. DoD lands in the United States and abroad include a large number of installations in coastal settings that are most vulnerable to climate change drivers (e.g., rising sea level, increased temperatures, extended periods of drought or flood conditions, extreme storm events [e.g., hurricanes, cyclones, nor'easters]). To better manage DoD lands and their infrastructure and natural assets, it is imperative that installation managers have accurate research findings to inform their management decision and prepare for future contingencies necessitated by changed climates. In addition, the carbon cycle is inextricably linked to climate change and its association with increasing concentrations of greenhouse gases (e.g., carbon dioxide [CO₂], methane [CH₄]) generated from the use of fossil fuels. DoD is a major consumer of fossil fuels used for military training and actual military engagements across the globe. Therefore, DoD is concerned about reducing its carbon footprint through the use of alternative

energy sources, improvements in energy conservation and efficiency, and resource management activities that address carbon management, including enhancements of carbon sinks, as an important ecosystem service consideration. Findings that result from these two thematic areas of research need to be communicated broadly not only to the scientific community, but also to installation managers to help them understand and assess potential vulnerabilities of coastal installations and to prepare contingencies to ensure sustainability of the military mission under future changed climate conditions.

2.0 Purpose of the Monitoring Plan

The purpose of the *DCERP2 Monitoring Plan* is to describe the monitoring activities that will be conducted at MCBCL and that will provide an historic reference of selected environmental parameters over the duration of the program. The DCERP2 monitoring objectives (summarized in **Table 2-1**) are focused on collecting both baseline environmental data and data following episodic events that can inform the research, modeling, adaptive management, and decision-support tool development. The components identified in the monitoring program are ones that need to be studied intensively and/or continuously over a long period of time to determine trends and natural variability in the various ecosystems especially in light of climate change impacts. The monitoring program will collect information at routine intervals and during episodic events such as those associated with climate drivers (i.e., changes in the trajectory and variability related to temperature and precipitation; changes in the frequency, magnitude, and storm track of extreme events; changes in sea level; and changes in the interactions among the preceding). The Climate Change Module, working in concert with each research project, will further refine these drivers (see the *DCERP2 Research Plan* for more information).

Table 2-1. DCERP2 Monitoring Objectives

Contribute to the scientific understanding of the physical, chemical, and biological processes that determine the stability and community structure of estuarine and coastal ecosystems and of the transformations and fluxes of materials (nutrients, carbon, and sediments) that flow between the estuary, coastal marshes, and land
Provide data to determine annual and inter-annual trends and natural variability of the parameters being monitored
Provide data to differentiate climatic, including extreme events, from anthropogenic stressors and their impacts on nutrient utilization, sediment transport, and carbon cycling
Provide data to support research, development, and verification of decision-support tools and models, including climate change scenarios

2.1 Summary of Monitoring Activities

Monitoring in the DCERP2 effort refers to data collection that will occur throughout the life of the program, be used by multiple research projects, provide broad context for interpreting research results, and provide data for calibration and verification of ecosystem simulation models. This Monitoring Plan builds on the *DCERP1 Monitoring Plan*, but this plan has been refocused to specifically include the estuary and coastal marshes with an emphasis on the relationships between nutrients, sediment, and carbon fluxes as mediated by climatic (hydrologic and thermal) and anthropogenic drivers (**Table 2-2**). The *DCERP2 Monitoring Plan* is designed to gather systematic time-series observations on responses to ecosystem stressors and indicators over a period of time sufficient to determine the existing status, trends, and natural variation of measured parameters. The *DCERP2 Monitoring Plan* is also designed to record, document, and assess extreme events and “ecosystem threshold events” or tipping points and to be responsive to changing research and management needs.

Table 2-2. Summary of Module-Specific Monitoring Activities

Module	Activities
Aquatic/ Estuarine	<u>Physical/hydrodynamics</u> : Temperature, light, and stream flow and discharge <u>Chemistry</u> : Carbon, chromophoric dissolved organic matter (CDOM), nutrients, salinity, pH, and oxygen <u>Sedimentology</u> : Suspended sediment concentration (New River), total suspended solids (New River Estuary [NRE]), and turbidity (NRE) <u>Biology</u> : Primary productivity, phytoplankton biomass and community composition, and benthic microalgal biomass
Coastal Wetlands	<u>Shoreline delineation</u> : Surface elevation change, topography, morphology, and marsh edge erosion <u>Hydrodynamics</u> : Tide gauges (water level, temperature, and salinity) <u>Marsh vegetation</u> : Distribution, composition, stem height, and grazer density (snails) <u>Sedimentology</u> : Sedimentation rates, organic content, and particle size

2.2 DCERP2 Monitoring Related to the DCERP1 Monitoring Effort

Based on DCERP1, DCERP2 researchers have a good understanding of the inputs of nutrients and their impact on the biological processes in the New River Estuary (NRE); however, for DCERP2, the monitoring focus has shifted the emphasis to carbon cycling—sources, uptake, turnover, loss, and burial. Because there is an inherent connection between nutrients and carbon cycling, these parameters must be captured together as part of a comprehensive monitoring program. The objectives of this program are to develop a carbon budget for the estuarine and coastal area and to understand changes in these processes under different climate conditions.

The *DCERP2 Monitoring Plan* is exclusively structured around the Aquatic/Estuarine and Coastal Wetlands Modules. This extension of the long-term monitoring of many parameters in these two programs is required to assess annual and inter-annual variabilities to meet the objectives of DCERP2, especially the focuses on carbon cycling and future climate change.

2.3 Adapting the Monitoring Plan

DCERP2 researchers will conduct routine assessments of their monitoring activities to evaluate the adequacy of the activities and adjust the monitoring effort to ensure its relevancy to the new DCERP2 thematic objectives and its cost efficiency. This includes an initial assessment during the 3-month planning period and an annual assessment at the end of each monitoring year. These assessments will determine whether (1) the temporal and spatial design of the monitoring is collecting adequate data to address DCERP2's research objectives, (2) data are collected using the most appropriate methods available with respect to measurement sensitivity and cost effectiveness, and (3) there are any significant annual and inter-annual trends in the data collected. Our experience has shown that, given the high inter-annual variability in many ecological and environmental parameters, assessing trends in many parameters is difficult without several years of monitoring data.

3.0 Aquatic/Estuarine Module

The following subsections of this section contain the proposed monitoring activities for the Aquatic/Estuarine Module, including background information on the module, the knowledge gaps in the conceptual model that the monitoring data will fill, and the individual monitoring activities that are proposed for implementation. Specific information is provided for each activity, such as its objectives and methods and the relationships within the module and among the other modules for each of the four implementation years.

3.1 Introduction

Estuaries integrate inputs from terrestrial, freshwater, oceanic, and atmospheric systems (Day and Kemp, 1989; Hobbie, 2000; Valiela et al., 1997). Accurate assessment of ecosystem function and management of estuaries necessitates consideration of their connections to, and interactions with, these other systems. Estuaries also exist in regions of rapidly expanding and diversifying human activity (Boesch et al., 2001; Cloern, 2001; Nixon, 1995). In the context of the MCBCL region, the Aquatic/Estuarine Module is examining the tidal reach of the NRE from near Jacksonville, NC, to the tidal inlet at Onslow Bay. Understanding of ecosystem function within the NRE requires quantifying and distinguishing natural processes from human-influenced watershed-based impacts, as well as human activities that occur in the estuary (see **Figure 3-1**; Boesch et al., 2001; Malone et al., 1999; Nixon, 1995; Paerl, 1997). Furthermore, the effects of climatic variability, including acute or episodic events (e.g., tropical cyclones, floods, droughts) and longer term trends (e.g., warming, precipitation patterns), on estuarine biogeochemical (nutrient and carbon) cycling and water quality must be characterized and quantified (Cloern and Jassby, 2010; Kennish and Paerl, 2010; Paerl et al., 2010). DCERP1 water quality monitoring on the NRE demonstrated significant, and at times, dominant effects that climate events and change can have on the nutrient inputs, water quality, trophic state, overall ecological condition, resourcefulness, utility (for military training and for commercial and recreational purposes), and sustainability of the NRE. Fortunately, the Aquatic/Estuarine Module monitoring design was able to capture the level of complexity and variability in biogeochemical and trophic responses needed to assess ecological condition and change of the NRE (Paerl et al., in preparation). Only long-term monitoring and modeling will reveal the full extent of anthropogenic and climatically induced perturbations and changes impacting this system. As new understanding of these ecosystem processes and stressors is gained during the course of DCERP2 research, the module-level conceptual model will be revised based on this new information.

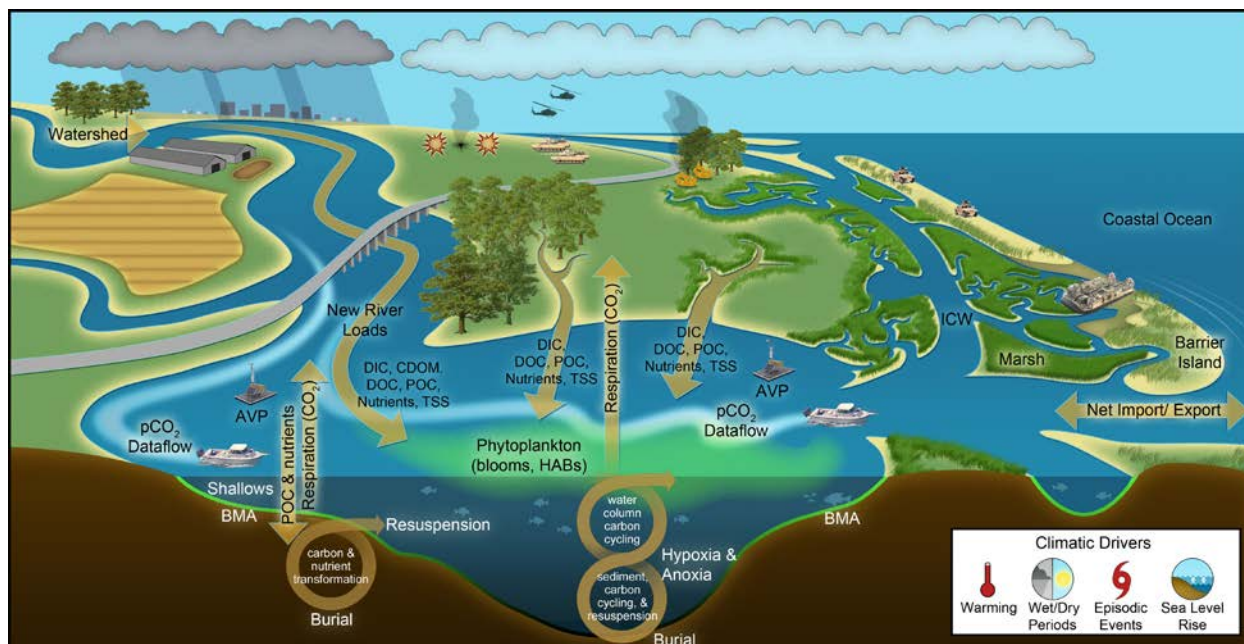


Figure 3-1. Conceptual model for the Aquatic/Estuarine Module.

3.2 Monitoring Objectives and Activities

The objectives of the Aquatic/Estuarine Monitoring Program (AEMP) are to provide information to

1. Understand the context in which complex interacting physical, chemical, and biotic processes drive estuarine water and habitat quality, including carbon, nutrient, dissolved oxygen (DO), and

- sediment fluxes under current conditions and for different climate change scenarios (i.e., warming, hydrologic changes, extreme events, and sea level rise)
2. Differentiate climatic, including extreme events, from anthropogenic stressors and their impacts on nutrient and carbon cycling
 3. Ensure compatibility and compliance of MCBCL activities with water and habitat quality management goals into the future
 4. Identify the ecosystem services provided by these natural resources for ecosystem, recreational, and economic benefits
 5. Provide data for decision-support tools and model calibration and verification. The AEMP will support the data needs of Research Projects AE-4, AE-5, AE-6, TSP-2, CW-4, CW-5, and CB-5.

The NRE is a dynamic ecosystem where primary production and the cycling of carbon and nutrients are strongly controlled by physical (hydrologic, tidal, wind, light)–chemical interactions operating over highly variable temporal and spatial scales (Ensign et al., 2004; Hall et al., 2011; Mallin et al., 2005; Paerl et al., 2011; Peierls et al., 2011). The AEMP will measure and assess the dynamic processes operating within the estuary, their relationships to terrestrial–wetlands, atmospheric, and oceanic inputs and exchanges (including nutrients, sediments, oxygen, and organic and inorganic carbon), and the complex geomorphology of the system (**Table 3-1**). The AEMP will document and link historic and contemporary trends in the important variables with respect to sources, effects, and modulation of major stressors, especially carbon, nutrients, oxygen, and sediments. Nutrient and carbon cycling and fluxes are closely tied to primary and secondary production, biodiversity, and biogeochemical changes, including hypoxia and anoxia. These processes play a critical role in controlling net estuarine carbon fluxes (e.g., net autotrophy versus heterotrophy, eutrophication). The AEMP will help clarify mechanisms underlying key pelagic and benthic biotic responses (e.g., primary production, algal biomass, respiration) to climatic and military and non-military stressors. The design will incorporate the appropriate temporal scales to capture episodic, synoptic, seasonal, and inter-annual cycles and trends that affect critical processes at local and regional spatial scales for the key estuarine habitats. Data management, statistical, geographical information systems (GIS) mapping, and modeling techniques will assist in identifying and distinguishing man-made and climatic forcings of ecosystem physical–chemical–biotic processes and attributes.

Two basic approaches will be used to monitor biological, chemical, and physical parameters. First, a consistent temporal–spatial long-term monitoring network will be implemented building on the current DCERP monitoring program. The network will capture all inputs to and outputs from the NRE, and document chemical and biological transformations that occur within the system. Stations extend longitudinally from the long-term U.S. Geological Survey (USGS) gauging station on the New River at Gum Branch to the estuarine-coastal ocean interface at the New River Inlet. The sampling network will include sites on freshwater and brackish tributary creeks draining into the New River system, and stations along the Intracoastal Waterway (ICW). Second, this adaptive sampling program will capture episodic event-scale (storm) impacts on the NRE; provide information on the land–water interface, specifically for assessing impacts of stormwater runoff, including carbon, nutrients, and sediment inputs; and provide data for calibrating models (i.e., Estuarine Simulation Model [ESM] developed during Research Project TSP-2) in real-world scenarios, where event-scale processes impact fluxes disproportionately to their duration. This will enable more realistic forecasts of climate change impacts. Episodic stormwater sampling will be adaptively modified as an improved understanding of the system is developed to capture a wide range of event types and land-use changes associated with military training activities and infrastructure development.

Table 3-1. Components of the Aquatic/Estuarine Monitoring Program

Component	Variable	Temporal Scale	Spatial Scale	Method	Team Lead ^a
AEM-1: Main body of NRE	Salinity, water temperature, DO, pH, turbidity, chlorophyll fluorescence, light (PAR)	Continuous (AVPs); monthly (manual profiles and Dataflow)	2 stations (AVPs); 8 stations (manual profiles), high resolution surface (Dataflow)	YSI multiparameter datasonde, LI-COR quantum sensor	HP, RL
	Nutrients (DIN [nitrate/ nitrite, and ammonium], DON, TDN, phosphate), dissolved carbon (DOC, DIC, and pCO ₂), and POC and PON	Bimonthly in winter, monthly spring–fall	8 stations (surface and near bottom), high resolution surface (pCO ₂)	Lachat flow injection analyzer (nutrients); infrared gas analysis (pCO ₂ and DIC), Shimadzu TOC analyzer (DOC), elemental analysis (POC and PON)	HP
	Phytoplankton biomass (chl <i>a</i>), PPR		8 stations (surface and near bottom)	Fluorometric–extracted and HPLC (chl <i>a</i>), ¹⁴ C light/dark method (PPR)	
	Phytoplankton community composition	As appropriate for voucher purposes	8 stations (near surface, near bottom)	Microscopic analyses	
AEM-2: Tributary creeks ^b	Tributary inflow, water level, conductivity, temperature	Continuous	5 stations	ADV, pressure transducer, conductivity-temperature-depth	MP
AEM-3: Shallow NRE	Salinity, water temperature, DO, pH, turbidity, chl fluorescence	Bimonthly and 3 episodic events per year ^c	3 stations and NRE peripheral (high-resolution Dataflow)	YSI multiparameter datasonde	IA, SE
	Nutrients (DIN, DON, TDN, phosphate), dissolved carbon (DOC, DIC, and pCO ₂), chl <i>a</i> , CDOM, TSS		6 stations	Lachat flow injection analyzer (nutrients); infrared gas analysis (pCO ₂ + DIC); Shimadzu analyzer (DOC); fluorometric–extracted (chl <i>a</i>); spectrophotometer (CDOM); gravimetric (TSS)	
	Benthic chl <i>a</i>	Bi-monthly	6 stations	Extraction and spectrophotometry	IA
AEM-4: New River	Water temperature, DO, conductivity, salinity	Monthly	New River at Gum Branch	YSI multiparameter datasonde	SE
	Nutrients (nitrate, ammonium, DON, TN, DIN, phosphate), carbon (DIC, POC, and DOC), chl <i>a</i> , and SSC			Lachat nutrient methods; CO ₂ + DIC by IRGA; DOC by Shimadzu analyzer; chl <i>a</i> and SSC by filtration	SE, HP

Note: AVP = Autonomous Vertical Profiler; CDOM = chromophoric dissolved organic matter; chl *a* = chlorophyll *a*; CO₂ = carbon dioxide; DIN = dissolved inorganic nitrogen; DIC = dissolved inorganic carbon; DO = dissolved oxygen; DOC = dissolved organic carbon; DON = dissolved organic nitrogen; HPLC = high-performance liquid chromatography; IRGA = infrared gas analyzer; NRE = New River Estuary; PAR = photosynthetically active radiation; pCO₂ = partial pressure of carbon dioxide; PON = particulate organic nitrogen; POC = particulate organic carbon; PPR = primary production; SCC = suspended sediment concentration; TDN = total dissolved nitrogen; TOC = total organic carbon; TSS = total suspended solids; YSI = Yellow Springs Instruments, Inc.

^a HP = Hans Paerl; IA = Iris Anderson; MP = Michael Piehler; RL = Rick Luettich; and SE = Scott Ensign.

^b Nutrients, carbon, and TSS data will be measured at these same five stations during Research Project AE-5.

^c Episodic precipitation or wind event sampling will be conducted at three stations for a subset of the variables.

3.3 AEM-1: New River Estuary

Biogeochemical processes (nutrient and carbon cycling) in the dynamic NRE ecosystem are strongly controlled by physical (hydrology, tides, wind)—chemical interactions operating over highly variable temporal and spatial scales (Ensign et al., 2004; Hall et al., 2012; Mallin et al., 2005; Peierls et al., 2012). The Aquatic/Estuarine Module monitoring effort will examine the processes operating within the estuary and their relationships to terrestrial-wetlands, atmospheric, and oceanic inputs and exchanges (including nutrients, sediments, and organic and inorganic carbon), and the complex geomorphology of the NRE. AEM-1 is a critical component of the Aquatic/Estuarine Module because it will document and link historic and contemporary trends in the important variables with respect to sources, effects, and modulation of major stressors, especially nutrients and sediments. AEM-1 is designed to inform the modeling and research projects and provide valuable independent products related to impacts of estuarine climate change and carbon cycling in the main body (open water) of the NRE.

A major finding from Aquatic/Estuarine Module monitoring program in DCERP1 was the important roles of episodic events in nutrient and carbon cycling (e.g., primary production). In DCERP2, AEM-1 has been specifically and strategically designed to capture these events, using a network of eight vertical profiling stations, two Autonomous Vertical Profilers (AVPs) located near upper and lower estuarine monitoring stations, and a high spatial resolution, water quality mapping system (Dataflow). Analysis of estuarine monitoring data from DCERP1 has confirmed that the sampling frequency (monthly during spring–fall, bi-monthly during winter) and the number and location of sampling sites are minimally needed to meet the monitoring goals for DCERP2. Stations are located in representative regions of the estuary that span the full gradient of salinity and tidal range. These regions are known to, at times, respond individually and uniquely to hydrologic and nutrient inputs, including storm events, floods, and droughts, reflecting climatic conditions and change. The sampling locations and strategies will capture these important events. Discrete event data and long-term trend data will be used in the quantification of nutrient inputs, primary production and phytoplankton biomass, and net carbon flux in the water column, thus providing the nutrient and carbon inputs, outputs, and transformation rates needed to develop ecosystem-level carbon budgets.

3.3.1 Objectives

Objective 1 is to determine the input, distribution, use, cycling, and fate of nutrients, inorganic and organic carbon, and sediments, as well as the associated physical–chemical drivers or modulators (e.g., freshwater discharge, DO, pH, salinity) affecting the productivity, carbon flux, trophic state, water quality, and habitat condition of the NRE. Sampling locations are stratified to assess the variability within the estuarine salinity zones, tidal, and mixing regimes. These locations will allow us to examine relationships to terrestrial, wetland, and oceanic regions and to determine the effects of specific military and non-military human activities (i.e., sediment and nutrient releases) and natural drivers (climatic) on water column physical, chemical, and biotic conditions (Objective 2). This monitoring activity is also designed to evaluate the short- and long-term effects of these drivers on the structure, function, and sustainability of the NRE in a regime of climatic variability (Objective 3). This monitoring activity will also serve as a critical source of data for supporting the Aquatic/Estuarine Module research and ecosystem-level modeling projects.

3.3.2 Relationships Within the Module and Among Other Modules

AEM-1 will collect the data necessary for conducting trend analysis and for distinguishing relative impacts of acute (event-scale), seasonal, and longer term scales of external and internal drivers on ecosystem biogeochemical and trophic responses. These data will also be used for spatially and temporally “scaling up” and filling technical and conceptual information gaps for Research Projects AE-4, AE-5, and AE-6 and for validating and revising stages of the ESM (Research Project TSP-2) to be

performed during DCERP2. Data obtained during AEM-1 will be highly complementary to and integrated with shallow water littoral zone and creek data (measured using similar monitoring techniques and equipment and reported in consistent units) that will be collected by AEM-2 and AEM-3. AEM-1 provides the empirical foundation for Research Projects AE-4, AE-5, and AE-6, TSP-2, CW-4, and CB-5. Lastly, AEM-1 will provide “seamless” data collection to better understand the context in which complex interacting physical, chemical, and biotic processes drive estuarine water and habitat quality, nutrient, and carbon fluxes under conditions of climate change (warming, hydrologic changes, extreme events, and sea level rise), by

- Differentiating climatic from anthropogenic impacts on ecosystem production and nutrient and carbon cycling processes; this includes effects of extreme events such as hurricanes, nor’easters, and upland floods and droughts.
- Providing information that will ensure compatibility and compliance of MCBCL activities with estuarine water and habitat quality standards into the future.
- Characterizing natural resources for ecosystem, recreational, and economic benefits.

3.3.3 Methods

3.3.3.1 Spatial/Site Locations

AEM-1 involves eight vertical profile stations, two continuous AVP stations, and a boat-mounted flow-through water quality mapping system (Dataflow) that will be deployed to provide spatial coverage of the NRE below Jacksonville, NC (**Figure 3-2**). As part of AEM-3, an additional upstream station at the U.S. Highway 17 Business bridge (**Figure 3-7**) will be sampled bi-monthly for the same parameters as the eight vertical profiler stations. This station is also sampled monthly by the North Carolina Division of Water Quality’s Ambient Monitoring System for basic water quality (temperature, DO, salinity, pH, turbidity, Secchi depth) and critical biological and chemical measurements (chlorophyll *a* [chl *a*], dissolved inorganic nitrogen [DIN], total dissolved nitrogen [TDN], total dissolved phosphorus [TDP]). Availability of this upstream data will greatly aid in understanding the biogeochemical transformations of carbon and nutrients within this highly reactive freshwater to brackish transition zone (Hall et al., 2012; Tomas et al., 2007). Recent work (Hall et al., 2012; Peierls et al., 2012) has shown that this distribution of sampling locations and transects is minimally required to capture freshwater and nutrient inputs and utilization throughout the estuarine salinity and tidal regimes. The stations are distributed throughout the estuarine salinity gradient and strategically located to evaluate impacts from military operations, respectively. The sampling network will measure key inputs to and outputs from the NRE, as well as sites of high productivity, algal bloom formation, and associated nutrient and oxygen-cycling characteristics. These locations represent a logical and essential extension of long-term data collection and trend analysis from DCERP1 monitoring activities (c.f. Hall et al., 2012; Paerl et al., 2012, submitted; Peierls et al., 2012). Lastly, the proposed monitoring design complements monitoring activities by MCBCL, the State of North Carolina’s (North Carolina Department of Environment and Natural Resources) ambient water quality monitoring program, the USGS gauging station and monitoring activities, and data collection in the NRE Basin and New River by local stakeholder groups.

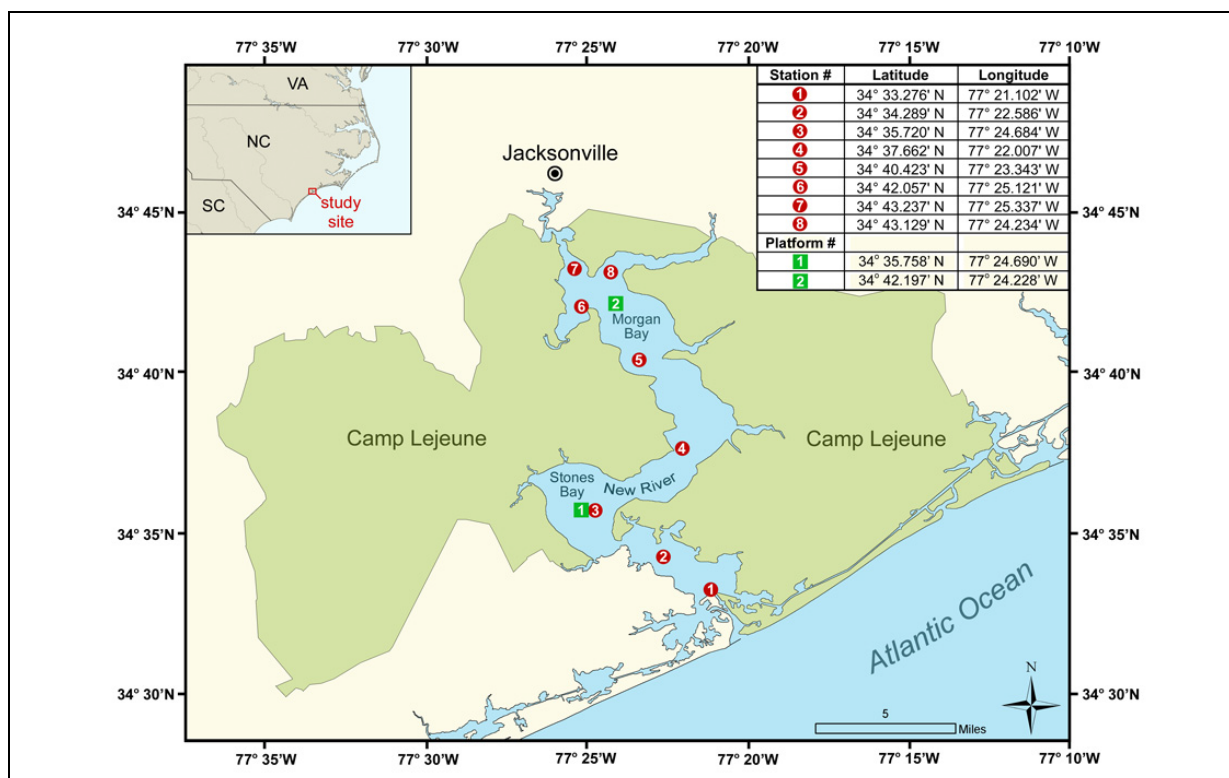


Figure 3-2. A map of the monthly and bi-monthly monitoring stations and the two AVP platform locations.

3.3.3.2 Temporal Considerations

AEM-1's design incorporates the appropriate temporal scales to capture episodic, synoptic, seasonal, and inter-annual cycles and trends that affect critical processes at local and regional spatial scales for the key estuarine habitats. The eight vertical profiling stations will be visited monthly from spring through fall (March–October), and bi-monthly during the winter (November–February). Dataflow transects, which constitute continuous surface traces of key environmental parameters (identical to vertical profiles) will be conducted during each sampling trip. In addition, AVPs will run continuously (collecting identical data on a 30-minute-per-profile frequency) at two locations representative of the NRE's range of hydrologic and tidal regimes. In addition, diel surveys along the length of the estuary will be conducted in conjunction with specific diel carbon and nutrient flux experiments outlined in Research Project AE-6. Lastly, flexibility has been built into AEM-1 to conduct "opportunistic" profile and Dataflow surveys in response to extreme events, such as tropical cyclones and droughts. It has been our experience during DECERP1 that such events can be major drivers of the NRE's net productivity and hence net carbon uptake dynamics and thus are important to capture. During such opportunistic efforts, monitoring will be extended upstream of Station 7 to include the station at the U.S. Highway 17 Business bridge. This will ensure that the full freshwater to polyhaline extent of the estuary is sampled simultaneously during key events. Frequencies and intensities of measurements along these scales must be complementary with ongoing modeling efforts, enabling researchers and managers to "scale up" from point measurements to watershed, and cross-system (air-water, land water, marsh-estuary) assessments. GIS, statistical modeling, and data management techniques will assist in distinguishing anthropogenic and climatic forcings of ecosystem physical–chemical–biotic processes and attributes.

3.3.3.3 Personnel

- Lead Investigators: Drs. Hans Paerl and Rick Luetlich
- Technicians: Two Field Technicians (each half-time), a part-time Electronics Technician (for AVP construction and maintenance), and a Graduate Research Assistant. Note: A boat crew of three, technically qualified individuals is minimally required to conduct water column transects (profiling, operating Dataflow, and calibrating and maintaining AVPs).

3.3.3.4 Parameters and Variables

- Salinity
- Water temperature (°C)
- Transparency (Secchi depth and photosynthetically active radiation [PAR])
- Dissolved oxygen (DO)
- pH
- Turbidity
- Chromophoric dissolved organic matter (CDOM)
- Chlorophyll *a* (chl *a*)
- Nitrate (NO₃⁻)
- Ammonium (NH₄⁺)
- Dissolved organic nitrogen (DON)
- Dissolved inorganic nitrogen (DIN)
- Total dissolved nitrogen (TDN)
- Phosphate
- Silicate (SiO₃⁻²)
- Dissolved organic carbon (DOC)
- Dissolved inorganic carbon (DIC)
- Partial pressure of carbon dioxide (pCO₂)
- Particulate organic carbon (POC)
- Particulate organic nitrogen (PON)
- Phytoplankton biomass and community structure
- Primary productivity

3.3.4.5 Field and Laboratory Procedures

Vertical Profile Stations

Vertical profiles of key water quality parameters will be collected from each of the eight stations using a Yellow Springs Instruments, Inc. (YSI) 6600 multiparameter datasonde coupled to a LI-COR 2π underwater quantum sensor. Temperature, salinity, pH, DO, turbidity, chlorophyll in vivo fluorescence, and PAR will be measured at 0.5-m-depth intervals throughout the water column. YSI instruments will be calibrated prior to each monthly monitoring cruise. Diffuse light (PAR) attenuation coefficients (K_d) will be calculated as the slope of the natural log of PAR versus depth according to Beer's law. Attenuation of light will also be measured by Secchi depth readings.

Coincident with monthly vertical profiles, water samples will be collected from the surface (0.2 m) and near bottom (0.5 m above the sediments) using a non-destructive diaphragm pump. Water samples will then be dispensed into 4-L polyethylene bottles and maintained under low light, in situ temperature

conditions by placing them in coolers until samples are delivered to the laboratory at the University of North Carolina at Chapel Hill's Institute of Marine Sciences (UNC-IMS). Samples will then be processed immediately upon delivery for measurements of nutrients, phytoplankton biomass, suspended sediments, and all carbon forms (dissolved and particulate and organic and inorganic).

Pre-combusted glass fiber filters will be used to filter surface and bottom water samples, which will then be colorimetrically analyzed for nitrate + nitrite ($\text{NO}_2^- + \text{NO}_3^-$), NH_4^+ , TDN, orthophosphate (PO_4^{3-}), and silicate (SiO_3^{2-}) using methods and equipment described by Wetz et al. (2011) and Hall et al. (2012). Soluble nutrient samples will be gently filtered (less than 20 kPa) through 25 mm in diameter Whatman glass fiber filters (0.7 μm nominal pore size). TDN, nitrate ($\text{NO}_3^- + \text{nitrite } [\text{NO}_2^-]$, labeled as NO_3^-), NH_4^+ , PO_4^{3-} , and SiO_3^{2-} concentrations will be determined using colorimetric flow injection analyses (Lachat QuickChem 8000, Lachat Instruments, Milwaukee, WI) and standard protocols (Lachat QuikChem methods 31-107-04-3-B, 31-107-04-1-C, 31-107-06-1-A, and 31-115-01-3-C, respectively). Detection limits for TDN, NO_3^- , NH_4^+ , PO_4^{3-} , and SiO_3^{2-} are 2.53, 0.04, 0.18, 0.06, and 0.75 $\mu\text{mol L}^{-1}$, respectively.

Filtrate will also be analyzed for DIC and DOC on a Shimadzu total organic carbon (TOC) analyzer (Model 5000A), and particulates retained on the filters will be analyzed for POC and PON on a Perkin Elmer, Model 2400 Series II carbon, hydrogen, and nitrogen (CHN) analyzer according to methods detailed by Peierls et al. (2003). Samples will also be analyzed for CDOM according to Lunetta et al. (2009) and total suspended solids (TSS) according to Standard Methods 2540 D (APHA, 1998) to develop relationships between light penetration and solids/chl *a* levels. ArcGIS and spatial statistics will be used to estimate average bathymetric areas for the 0- to 1-m, 1- to 2-m, and greater than 2-m depth intervals to calculate nutrient and carbon loads.

Chl *a*, a measure of total phytoplankton biomass, will be determined from all water samples collected at the monitoring stations according to methods described by Wetz et al. (2011). Accessory photopigments representing major phytoplankton classes will be measured using high-performance liquid chromatography (HPLC) from surface- and bottom-water samples at the sampling stations. Sample preparation, extraction procedures, HPLC column configuration, and analyses of the eluents are fully detailed in Pinckney et al. (2001). Dominant photopigments that were measured and algal divisions common to the NRE that contain them are presented in Hall et al. (2012). Surface- and bottom-water samples from the sampling stations were preserved for microscopic phytoplankton analyses using a 1% Lugol's solution. Causative species of phytoplankton blooms will be identified and quantified using inverted microscopy (Utermöhl, 1958).

Dataflow Measurements

High spatial-resolution transects of key water quality parameters will be produced for surface waters of the NRE using a boat-mounted, flow-through water quality mapping system (termed Dataflow after Madden and Day, 1992) shown in **Figure 3-3**. The Dataflow system will be used coincidentally with monthly/bi-monthly sampling efforts to expand the spatial resolution of the downstream transect produced by the eight discrete fixed sampling stations. While the vessel is underway, surface waters enter the Dataflow system via a through-hull fitting in the bottom of a research vessel (Parker 25). Water is then pumped through a debubbler into a flow-through chamber where a YSI 6600 multiparameter water quality datasonde measures salinity, temperature, DO, turbidity, pH, and chlorophyll *in vivo* fluorescence. With a 0.5-Hz sampling frequency, the spatial resolution is approximately 10 m at a normal forward speed of approximately 20 km hr^{-1} . The YSI datasondes will be calibrated prior to each transect.

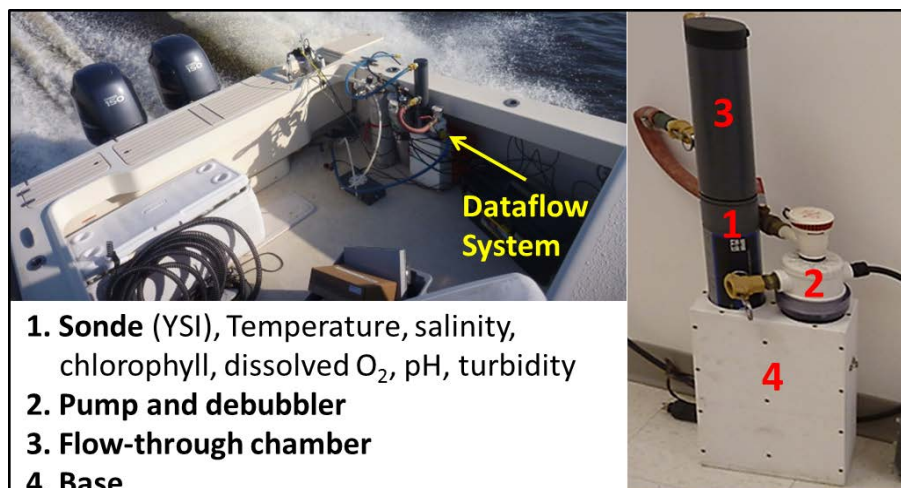


Figure 3-3. Diagram showing the primary components of the Dataflow system.

Autonomous Vertical Profilers

Two AVPs have been in place since June 2008, one in Stones Bay at Platform 1 and the other upriver in Morgan Bay at Platform 2 (**Figure 3-2**). The AVPs consist of a moored, floating platform that houses a computer controlled winch mechanism (**Figure 3-4**; Reynolds-Fleming et al., 2002). Semi-hourly casts of a YSI 6600 datasonde produce full water column profiles of temperature, salinity, DO, chlorophyll in vivo fluorescence, and turbidity. The YSI datasondes are programmed to sample once per second, and data are collected during the descent from surface to bottom at a velocity of approximately 4 cm s⁻¹, giving an approximate 4-cm depth resolution. Anemometers (RM Young Marine Wind Monitor 0510) mounted approximately 4 m above the water line measure 6-minute averages of wind speed and direction every 30 minutes. All data are stored on-board and telemetered to UNC-IMS nightly for processing. Deployed datasondes are exchanged with freshly cleaned and calibrated datasondes monthly, or sooner if necessary due to excessive drift in the data, malfunction, or biofouling.

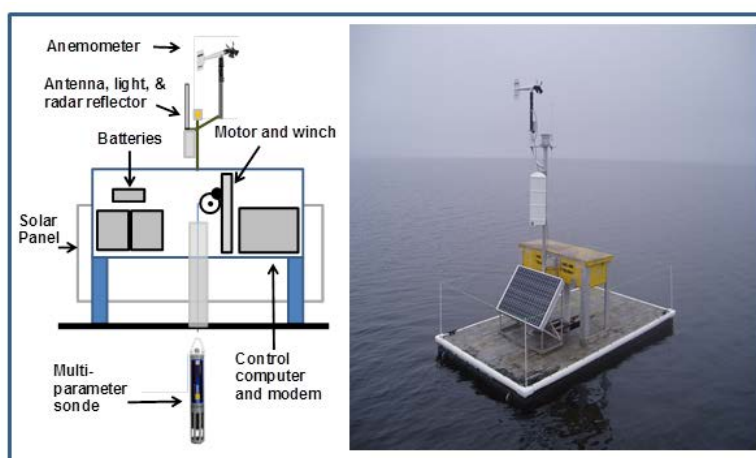


Figure 3-4. (Left) The primary components of the AVP systems and (right) a photograph of the AVP deployed in Stones Bay.

Utility and Benefits of AVPs as Part of the Overall AEM-1 Monitoring Program

The AVPs provide continuous monitoring data at two locations within the NRE (at Stones Bay and Morgan Bay; see **Figure 3-2**). This monitoring activity provides constant feedback on current water

quality conditions, including phytoplankton concentrations, where excessive chl *a* concentrations may indicate nuisance algal blooms; oxygen concentration profiles, which alert to the onset of hypoxic or anoxic conditions; and turbidity profiles, which can reveal sediment resuspension, a known “major stressor” in estuarine systems. The AVPs also monitor local wind velocity, which is one of the major physical forcing mechanisms in the NRE. The AVPs, having occupied each site since June 2008, are contributing to long-term monitoring efforts by establishing seasonal and annual trends, as well as episodic, synoptic, and baseline data.

The high temporal resolution (half-hourly) of the AVP observations are invaluable for capturing the variability of the system at periods less than the monthly/bi-monthly water quality sampling. Quantification of the variability at hourly to weekly time scales that is captured by the AVP provides a means to rigorously determine the fraction of variability that is missed during the monthly/bi-monthly monitoring transects. Additionally, knowledge of the short-term and vertical variabilities of the measured parameters provides a framework for understanding the mechanisms that drive spatio-temporal patterns in water quality detected by monthly monitoring. For example, data from the AVPs have demonstrated the importance of sediment resuspension in driving high levels of turbidity in the lower NRE. The AVPs have also shown that near surface accumulations of phytoplankton biomass that are commonly observed during monthly sampling are due to diel vertical migrations of bloom forming flagellates (Hall et al., 2012). The AVPs also provide key information on event-scale processes, particularly storm impacts, that would be impractical or unsafe for other monitoring activities.

AVP Data Post-processing

AVP data are post-processed in several steps before they are ready for analysis. These steps include filtering, outlier elimination, visual inspection, and post-calibration sensor correction. The on-board filtering in the YSI 6600 datasondes is turned off during data collection because the time lag in the filter response while the datasonde is moving vertically would cause a vertical shift in features measured within the data stream. To eliminate instrument-level noise and avoid this vertical shift, the optical sensor data for turbidity and chlorophyll fluorescence are smoothed in post-processing with a bi-directionally applied second-order Butterworth low-pass filter with a 10-second period. Data from the other sensors are left unfiltered. Next, data are checked for outlier values, and extreme or physically unrealistic values are removed (e.g., temperatures greater than 40°C caused by probe failure). All data are then subjectively checked visually. This allows elimination of data for reasons that would be difficult to detect objectively such as profiler malfunctions and biofouling. Post-calibration corrections are then applied to the data based on the following techniques:

- When the datasondes are exchanged, the old (previously deployed) and the new (about to be deployed) datasondes are placed side by side in a water sample and simultaneous observations are made.
- AVP profiles from the old and new datasondes taken adjacent in time are compared.
- During post-processing, values are compared across the entire time series to help detect if a newly deployed datasonde had problems with the laboratory calibration.

Equipment Used

Field

Field equipment includes a research vessel (25-ft Parker), equipped with a Dataflow system, YSI 6600 datasondes and data loggers, pCO₂ analyzer, water sampling equipment, global positioning system (GPS), and other navigational equipment. AVPs equipped with YSI 6600 datasondes.

Laboratory

Laboratory equipment includes incubation ponds (at UNC-IMS) for maintaining *in situ* light and temperature conditions for determining primary productivity and ancillary biological rate/biogeochemical flux measurements. Additional equipment includes a Lachat Instruments nutrient flow injection analyzer, a Shimadzu Model LC 20A high-performance liquid chromatograph, a Shimadzu Model 5000A TOC analyzer, a Perkin Elmer Model 2400 Series II CHN analyzer, a Turner Trilogy fluorometer, a Varian Cary Eclipse spectrofluorometer, a Shimadzu UV-1700 spectrophotometer, a Beckman-Coulter LS6500 scintillation counter, a Barnstead Nanopure water purification system, and Microsoft Windows-based PCs.

3.3.3.6 Data Management

Initially, data collected within the DCERP2 monitoring effort will be stored locally in a flat-file database after appropriate quality assurance (QA) and quality control (QC) procedures are complete. All files will be backed up weekly and stored both onsite (UNC-IMS, Morehead City, NC) and offsite. At 6-month intervals, the data output from AEM-1 will be transposed into Electronic Data Delivery (EDD) templates as prescribed by the DCERP Data Policy and uploaded to the DCERP Data and Information Management System (DIMS).

3.3.4 Data Analysis for Assessment of Trends

Long-term trends in the combined data set from DCERP1 and DCERP2 will be assessed using appropriate trend analysis techniques that are designed to account for serial autocorrelation and non-stationary behaviors. Examples include Seasonal Kendal Tau or Autoregressive Integrated Moving Average (ARIMA) models such as a Box-Jenkins analysis. In addition to determining the long-term trend, these methods will provide estimates of seasonality within key water quality and carbon flux parameters that will aid in predicting shorter term variability. Other time-series techniques such as Fourier power spectra, wavelet analyses, and coherence spectra may also be used to investigate dominant modes of variability within the time series and to understand the temporal scales at which interrelationships between parameters exist.

3.3.5 Products and Outcomes

The products and outcomes of AEM-1 are as follows:

1. Provide data on ecosystem nutrient cycling and fluxes in response to human (nutrient enrichment, sedimentation) and climatic pressures/stresses in the NRE. These data are necessary for conducting trend analysis; distinguishing relative importance of acute (event-scale), seasonal, and longer term impacts of external and internal drivers on ecosystem biogeochemical and trophic responses (with an emphasis on carbon); and spatially and temporally “scaling up” and filling technical and conceptual information gaps for Research Projects AE-4, AE-5, and AE-6. These data are also necessary for validating and revising stages of ESM modeling (Research Project TSP-2) to be performed during DCERP 2.
2. Differentiate climatic from anthropogenic drivers (and their impacts) on ecosystem production and nutrient and carbon cycling processes. This includes effects of extreme events such as hurricanes, nor’easters, droughts, and upland floods. For example, the AVPs will provide a long-term, nearly continuous, time series with wind velocities and vertical profiles of temperature, salinity, turbidity, pH, DO, and chlorophyll fluorescence. Raw (uncorrected) data are available daily, which provides information for rapid deployment of additional monitoring efforts in response to important events (e.g., storms, sewage spills). Example data shown in **Figure 3-5** illustrate the impacts on key water quality parameters at both AVP sites during the recent offshore passage of “Superstorm” Hurricane Sandy on October 27–28, 2012. The strong north

winds led to destratification of the water column, sediment resuspension, and rapid cooling events at both AVP sites.

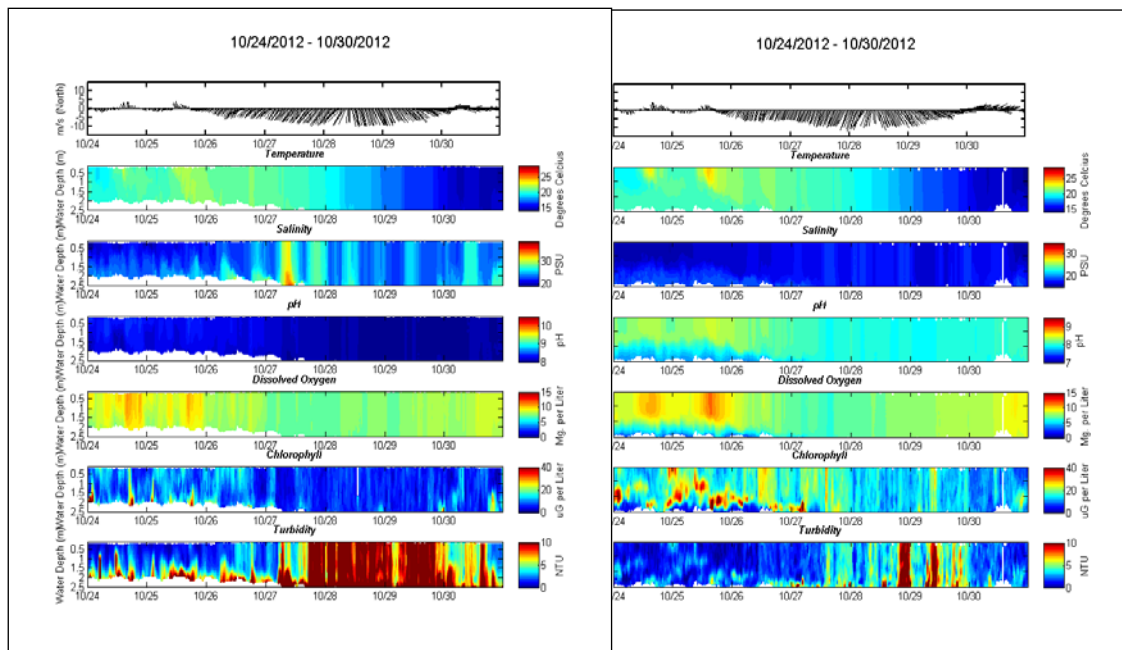


Figure 3-5. Data from the AVPs at Stones Bay (left) and Morgan Bay (right) during the offshore passage of Hurricane Sandy on October 27 and 28, 2012.

3. Serve as a key source of information to ensure compatibility and compliance of MCBCL activities with estuarine water and habitat quality standards into the future.
4. In support of Research Projects AE-4, AE-5, AE-6, CW-5, CB-5, and TSP-2, serve as a key informational source to develop an estuarine/coastal carbon budget that will be able to evaluate the NRE's response (in terms of carbon fluxes) to future trends in human and climatically driven changes and to determine whether the NRE is a carbon sink or source and its role in carbon management (mediating carbon credits and trading).

3.4 AEM-2: Tributary Creeks

3.4.1 Objectives

Water level, water velocity, conductivity, and temperature will be measured in each of the five coastal tributary creeks that flow to the NRE. Stream flow will be compared to precipitation intensity, duration, and frequency using meteorological data. Creek sampling stations are spatially stratified to assess variability within the estuarine salinity zones and to determine the effects of land activities on stream flow, temperature, and conductivity. Flow, temperature, and conductivity will be related to land use to link land activities and aquatic and estuarine ecosystem function.

3.4.2 Relationships Within the Module and Among Other Modules

AEM-2 will be directly linked to other aquatic/estuarine monitoring and research activities. Creek sites are the upstream-most sites in the monitoring program. Delivery of freshwater from creeks to the estuary is an important materials transport mechanism. Flow from AEM-2 and concentration measurements of carbon, nutrients, and sediments from Research Project AE-5 will be used to assess loading of these materials. Loading is often affected by changes in land activities in the watershed and thus can be connected to management decisions. This monitoring activity will also be linked to the Coastal Wetlands

Module. Freshwater flow affects the type of marshes present. Additionally, flow measurements from AEM-2 will be used with suspended solid concentrations from Research Project AE-5 to calculate delivery of beneficial materials to augment marsh accretion. The ability of many marshes to maintain their elevation is dependent upon a constant supply of suspended sediments. These monitoring activities will also be linked to the Terrestrial Module. The stream sampling sites represent an integration of the effects of watershed processes on the load of carbon, nutrients, and sediments transported from the landscape.

3.4.3 Methods

3.4.3.1 Spatial/Site Locations

The creek monitoring sites are distributed throughout the estuarine salinity gradient and are representative of watersheds with a variety of MCBCL land uses (e.g., industrial, forested, residential, training). The sites are illustrated in **Figure 3-6**, and their watershed characteristics are detailed in **Table 3-2**.

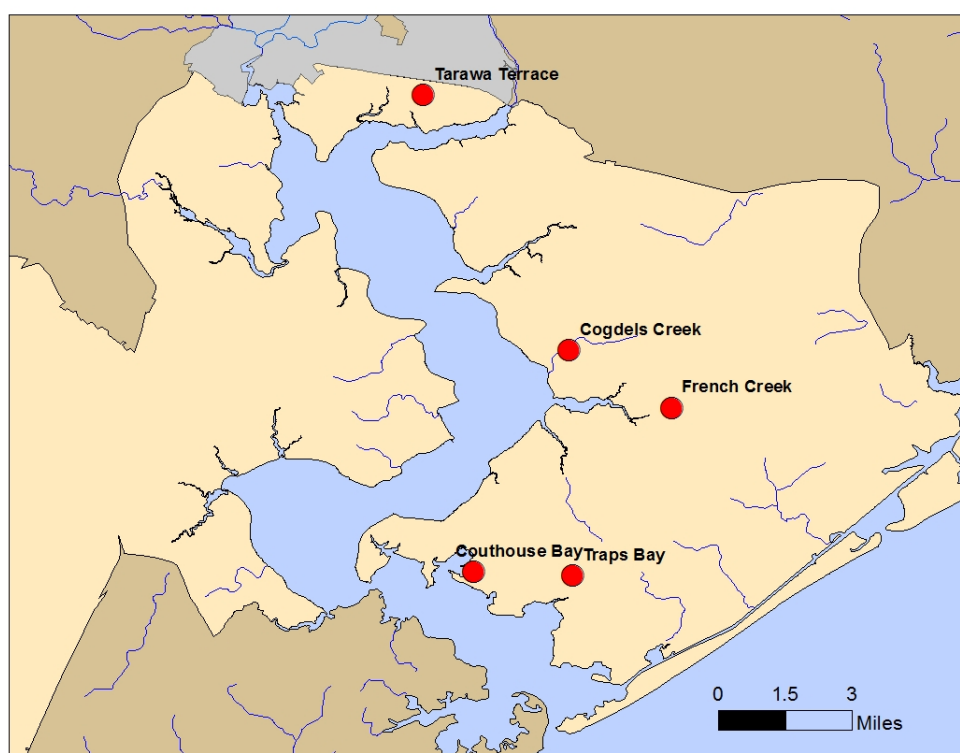


Figure 3-6. Tributary creek monitoring sites.

Table 3-2. Land Cover and Watershed Area of the AEM-2 Stream Study Sites

Site	Forested Land (ha)	Impervious Surface (ha)	Developed Land (ha)	Total Area (ha)
Cogdels Creek	280.53	115.25 (13.8%)	209.16	835.83
French Creek	80.28	8.56 (1.1%)	27.72	807.30
Tarawa Terrace	24.48	32.28 (23.2%)	63.90	139.14
Courthouse Bay	3.06	4.85 (15.5%)	19.62	31.32
Traps Bay	5.76	2.11 (4.13%)	6.39	51.03

3.4.3.2 Temporal Considerations

Water level, velocity, conductivity, and temperature will be measured at each of the creek sites continuously at 15-minute intervals for 4 years.

3.4.3.3 Personnel

- Lead Investigator: Dr. Michael Piehler
- Technician: One Field/Laboratory Technician

3.4.3.4 Parameters and Variables

- Tributary inflow
- Water level
- Conductivity
- Water temperature (°C)

3.4.3.5 Field and Laboratory Procedures

Sampling Design and Collection

Standard methods will be used for all data collection, processing, and archiving. Streamflow data collection methods will be derived from Morlock et al. (2001), Oberg et al. (2005), Ruhl and Simpson (2005), and Simpson (2002). Conductivity and temperature measures will be made with a YSI 600 described below.

Equipment Used

Field

Field equipment will include pressure transducers to measure water level, ISCO acoustic Doppler velocimeters to measure stream velocity, and YSI 600 multisensor datasondes to measure physical properties (temperature, conductivity).

Field equipment will be monitored routinely, and information will be obtained on performance in conjunction with each use of the equipment. This information will be stored in log books maintained with each piece of equipment. The information will be reviewed weekly by the UNC-IMS staff and monthly by the Lead Investigator. Maintenance of equipment used in this project is the responsibility of the Lead Investigator. Routine maintenance and minor repairs is the responsibility of the Field Technician. Appropriate in-house repairs will be performed by UNC-IMS maintenance staff, and remaining repair activities will be conducted by manufacturer repair experts. Records of all significant preventive maintenance activities will be maintained with the instruments.

Laboratory

No laboratory equipment will be used for AEM-2.

3.4.3.6 Data Management

Data downloaded from loggers will be checked by technical staff. Laboratory notes and data will be recorded daily in bound laboratory notebooks. Information entered into notebooks from machine printouts will be verified twice, and the originals will be filed in Dr. Piehler's laboratory. Data entered from notebooks into computer files will be verified and validated. At 6-month intervals, the data output from AEM-2 will be transposed into EDD templates as prescribed by the DCERP Data Policy and uploaded to the DCERP DIMS.

3.4.4 Data Analysis for Assessment of Trends

Data will be subjected to statistical analyses, including time series analyses of flow, conductivity, and temperature. Seasonal comparisons will be made within and among sites. Errors will be detected by abnormally high variation in patterns of flow, conductivity, and temperature at each site. If high variability continues to be observed, this will indicate a problem in materials used in the analysis or procedures followed by the personnel. Should this arise, an immediate and thorough review of materials and procedures will be conducted by the Lead Investigator, and the appropriate corrective actions will be taken.

Concentrations of carbon, nutrients, and suspended solids from grab samples taken in Research Project AE-5 will be used in conjunction with the velocity measurements to estimate loading of those materials. Loading will be analyzed relative to meteorological drivers such as precipitation and anthropogenic drivers such as land use.

3.4.5 Products and Outcomes

The products of AEM-2 will include the following:

1. Monthly measurements of tributary freshwater inflow to the estuary from five representative creeks and hourly conductivity and temperature in creeks for use in other DCERP activities
2. Assessment of the relationship between air and creek temperature during the study period
3. Assessment of conductivity (and salinity) patterns, including the meteorological and anthropogenic drivers
4. Reports for decision makers detailing monitoring data that emphasizes patterns in flow, salinity, and temperature and connects to a land development metric such as imperviousness will be delivered in 2015 and 2017.

3.5 AEM-3: New River Estuary—Shallows

3.5.1 Objective

Water quality parameters, including DO, carbon, nutrients, TSS, chl *a*, and benthic chl *a* (a measure of benthic microalgal biomass) will be measured in the shallow zone along the periphery of the NRE. In addition, YSI multisensor datasondes will be deployed to measure diel variations in DO and water quality in the shallows of three regions of the estuary. Additional deployments of datasondes will be made to capture changes in shallow DO and water quality during and after episodic events that are necessary for calibrating and validating models of estuarine productivity and trophic state. Shallow water sampling stations will be spatially stratified to assess variability within the estuarine salinity zones. AEM-3 is designed to respond to the thematic focus areas of DCERP2, in particular carbon cycling and climate change. During DCERP1, the Aquatic/Estuarine Module Team noted strong biotic responses to natural and anthropogenic disturbances. For example, results from DCERP1 Research Project AE-3 found that the effectiveness of the benthic filter in mitigating nutrient enrichment and eutrophication was dependent upon light availability, which varied in response to freshwater discharge from the New River, CDOM, and particulate concentrations (TSS). The benthos was shown to account for more than 40% of primary production in the entire estuary. Thus, it is essential to monitor benthic microalgae (BMA) and the shallow water zone where benthic and pelagic production and respiration are strongly linked to determine sources, sinks, and transformations of carbon in the NRE.

3.5.2 Relationships Within the Module and Among Other Modules

Because more than half of the estuary has water depths of less than 2 m (MSL), AEM-3 will provide shallow water data necessary to produce the estuarine/coastal carbon budget, along with monitoring

activities of AEM-1 and AEM-2 and Research Projects AE-4, AE-5, AE-6, CW-4, CW-5, CB-5, and TSP-2. AEM-3 and Research Project AE-6 will focus on the shallow zone around the periphery of the estuary where light may reach the benthos supporting benthic autotrophy and nutrient uptake. AEM-1 and Research Project AE-4 will sample primarily in the deeper channel zone of the NRE and AEM-2 and Research Project AE-5 will sample in the smaller creeks. Water quality monitoring by AEM-3 will be conducted by Dataflow cruises along the entire periphery of the NRE and will provide water quality, DO, nutrient, CDOM, chl *a* (benthic and pelagic), and TSS data in response to different climatic conditions, including those following episodic events. Research Project AE-6 is focused on determining estuarine-wide net exchanges of CO₂ between the water column and atmosphere over time scales that vary from diel to monthly, annually, and inter-annually. To capture diel variation, Research Project AE-6 Dataflow cruises will be conducted along one shoreline of the NRE at dawn, dusk, and the following dawn. YSI deployments at three fixed stations (upper, middle, and lower estuary) by AEM-3 will provide DO and physicochemical data necessary to support determinations by Research Project AE-6 of estuarine trophic state (autotrophy versus heterotrophy), including measures of net ecosystem metabolism, primary production, and respiration.

3.5.3 Methods

3.5.3.1 Spatial/Site Locations

The periphery of the NRE in the shallow water zone will be sampled continuously (approximately every 30 m or 2 seconds) with a Dataflow system fitted with sensors for pCO₂, salinity, pH, temperature, DO, turbidity, chlorophyll, and CDOM. At six sites distributed throughout the estuarine salinity gradient in the shallow water zone (approximately 1 m water depth at MLW; **Figure 3-7**), water samples will be collected in triplicate for analyses of dissolved nutrients, DIC, DOC, TSS, chl *a*, and CDOM. Sediment samples will also be collected for analysis of benthic chl *a*, a measure of benthic microalgal biomass. At three of these sites, spatially located to represent the NRE, YSI multisensor datasondes will be deployed for measurements of salinity, pH, temperature, DO, turbidity, chlorophyll, and water depth above sensors. The exact location of AEM-3 stations will be determined following site visits to the NRE.

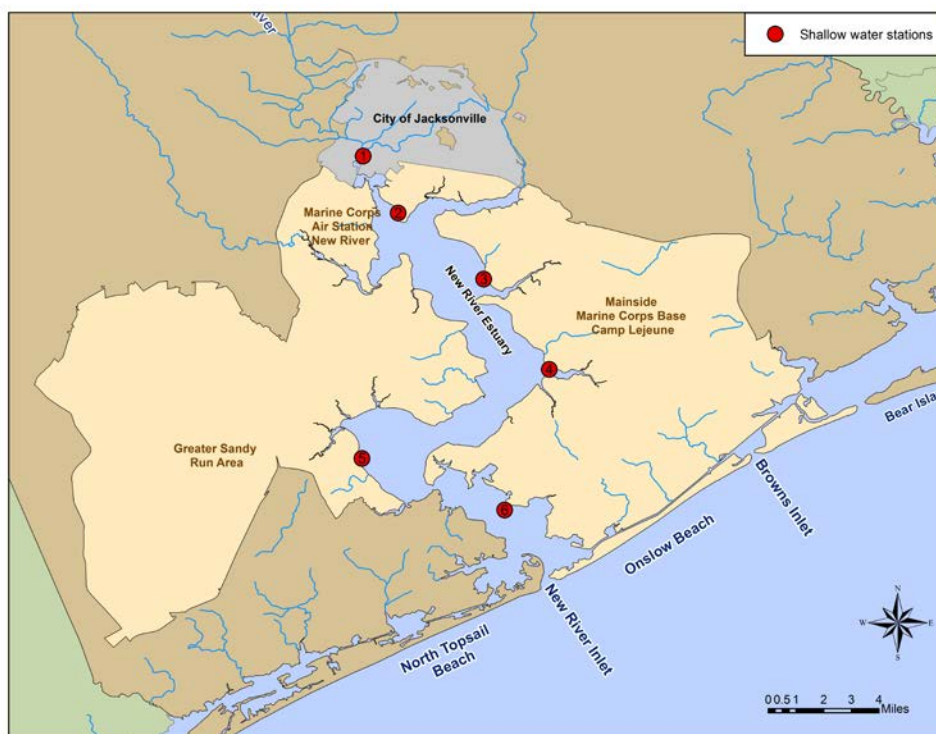


Figure 3-7. NRE shallow water monitoring stations.

3.5.3.2 Temporal Considerations

Routine monitoring at all six sites and the NRE periphery (Dataflow) will be conducted concurrently on a bimonthly basis. At three of these sites (Stations 2, 4, and 5), YSI multisensor datasondes will be deployed bimonthly for 5–7 day periods. In addition, the datasondes will be deployed at these three stations after episodic events (up to three events per year). Episodic events may influence near-shore benthic productivity, therefore, the datasonde will be deployed for 5 days (continuously recording salinity, water temperature, DO, and water depth) and water samples will be collected on the first and last days for analyses of nutrients, DIC, DOC, chl *a*, and TSS. Both precipitation and wind events, independently or in conjunction, will be targeted for sampling. “Precipitation events” will be defined as those with greater than 2.5 cm of rain in a 24-hour period, and “wind events” will be defined as those with an average daily wind speed greater than the 90th percentile. The 90th percentile of daily wind speed–based recordings from the meteorology station at Marine Corps Air Station New River (Station name: KNCA) is 4.9 m s⁻¹ based on the period of 1956–2012.

3.5.3.3 Personnel

- Lead Investigator: Dr. Iris Anderson
- Supporting Researcher: Dr. Scott Ensign
- Graduate Student: One graduate Research Assistant
- Technicians: Two Field and Laboratory Technicians

3.5.3.4 Parameters and Variables

- Partial pressure of CO₂ (pCO₂)
- Salinity (ppt)
- Water temperature (°C)
- Dissolved oxygen (DO)
- pH
- Turbidity
- Chlorophyll *a* (chl *a*; YSI and in vitro fluorescence)
- Benthic chl *a* (0- to 3-mm depth horizon)
- Nutrients (dissolved inorganic nitrogen [DIN; nitrate, nitrite, and ammonium], dissolved organic nitrogen [DON], phosphate)
- Carbon (dissolved inorganic carbon [DIC], dissolved organic carbon [DOC])
- Total suspended solids (TSS)
- Chromophoric dissolved organic matter (CDOM)

3.5.3.5 Field and Laboratory Procedures

Sampling Design and Collection

At each station, water samples will be collected in triplicate with 250-mL, brown Nalgene bottles for nutrient, CDOM, chl *a*, and DOC analyses; glass hungate vials (spiked with zinc chloride [ZnCl₂]) for DIC analyses; and 125-mL Nalgene bottles for TSS analyses. Water samples will be filtered (polyethysulfone, 0.45 µm) and frozen until analyzed for DIN (which includes ammonium, nitrate, nitrite), phosphate, DOC, and DON using standard methods listed in **Table 3-3**. Water column chl *a* and phaeophytin will be filtered onto glass fiber filters (0.7 µm) and frozen until analysis. TSS will be determined by filtering the entire 125-mL sample volume through preweighed, combusted glass fiber filters (0.7 µm) and then drying to constant weight. Sediment will be collected with 5-mL NormJect syringes (with the tips cut off flat) and the 0- to 3-mm-depth horizon will be sub-sampled for benthic chl

a analysis and frozen until analysis (less than 1 month). Water samples for CDOM determinations will be prefiltered through glass fiber filters (0.7 μm) followed by a polycarbonate filter (0.22 μm) and frozen until analysis. After the above samples are frozen, they will be analyzed as listed in **Table 3-3**.

Table 3-3. Summary of Analytical Methods Used for AEM-3

Analyses	Methods/Instrument	References
Benthic chlorophyll <i>a</i> (chl <i>a</i>) and phaeophytin (microalgae biomass)	chl <i>a</i> –acetone extract/spectrophotometry; Shimadzu UV-1800 spectrophotometer	Lorenzen, 1967; Neubauer et al., 2000
Chl <i>a</i> (extracted; phytoplankton biomass)	chl <i>a</i> –acetone–dimethyl sulfoxide (DMSO) extract/fluorometry; Turner Designs Model 10-AU fluorometer	Arar and Collins, 1997; Shoaf and Lium, 1976
Chromophoric dissolved organic matter (CDOM)	WET Labs CDOM sensor, Shimadzu UV-1800 spectrophotometer (absorption read at a wavelength of 440 nm)	Gallegos and Neale, 2002; Green and Blough, 1994; Kirk, 1994
Nitrate + nitrite ($\text{NO}_2^- + \text{NO}_3^-$)	Cadmium reduction/diazotization (Lachat ^a)	Smith and Bogren, 2001
Ammonium (NH_4^+)	Phenol hypochlorite method (Lachat ^a)	Liao, 2001
Phosphate (dissolved inorganic phosphorus [DIP])	Molybdate method (Lachat ^a)	Knepel and Bogren, 2001
Total dissolved nitrogen (TDN)/dissolved organic nitrogen (DON)	Alkaline persulfate digestion (Lachat ^a)	Koroleff, 1983
Dissolved inorganic carbon (DIC)	Acidification to carbon dioxide (CO_2); LI-6252 CO_2 analyzer	
Dissolved organic carbon (DOC)	680°C catalytically aided combustion oxidation/nondispersive infrared detection; Shimadzu total organic carbon-V analyzer	Neubauer and Anderson, 2003

^a The Lachat auto analyzer (QuikChem 8000 automated ion analyzer, Lachat Instruments, Loveland, CO) is a continuous flow automated analytical system that complies with U.S. Environmental Protection Agency standards.

Calibration of YSI multiparameter datasondes will follow protocols recommended by YSI for unattended deployments and Dataflow surveys. YSI datasondes will be deployed from three fixed stations (attached to piling) at a fixed depth (0.5 m above the bottom in total water depth of approximately 1 m at MLW) bi-monthly and following three episodic events, as previously described. The pCO_2 -Dataflow system will be operated from a small boat, all instrumentation will be examined, and the pCO_2 analyzer will be calibrated before and after each Dataflow survey, as described by Crosswell et al. (2012).

Equipment Used

Field

Field equipment will include three YSI 6600 multiparameter datasondes for deployments at fixed stations and three YSI 600 Optical Monitoring System (OMS) datasondes with 6150 ROX Optical DO probes and YSI 650 Multiparameter Display System for deployments at fixed stations after episodic events. Equipment will also include the pCO_2 -Dataflow system, which includes the LI-COR Model 840 infrared gas analyzer, the YSI 6600 multiparameter datasonde, a WET Labs CDOM sensor, a Garmin GPS, and a LabVIEW data acquisition system.

Laboratory

Laboratory equipment will include a Lachat QuikChem 8000 automated ion analyzer, a Shimadzu TOC-V analyzer, a LI-COR Model LI-6252 CO_2 analyzer, a Turner Model AU-10 fluorometer, and a Shimadzu UV-1800 spectrophotometer.

3.5.3.6 Data Management

Data downloaded from loggers will be checked by technical staff (QA and QC). Laboratory notes and data will be recorded daily in bound laboratory notebooks. Field and YSI calibration data will be recorded on specially prepared data sheets, stored in the laboratory in binders, and transferred to electronic files. Information entered from handwritten field datasheets and laboratory notebooks will be verified twice and validated. Two copies (backup and original) will be kept of all computer files at all times.

YSI datasondes post-calibration data will be checked to be sure that any drifts in the probes are within acceptable ranges (**Table 3-4**); if these are not in the range, then appropriate error codes will be used to identify these data. Once these checks have been accomplished, the data can be put into the final form for submission.

Table 3-4. Acceptable ranges in drift for water quality parameters for AEM-3

Parameter	Value
Chlorophyll (fluorescence)	±5% of true value
Dissolved oxygen	±0.5 mg/L
pH	±0.2 pH units
Specific conductance	±5% of true value
Turbidity	±5% of true value
Water temperature	±0.2°C

At 6-month intervals, the data output from AEM-3 will be transposed into EDD templates as prescribed by the DCERP Data Policy and uploaded to the DCERP DIMS. This system securely stores data and makes them available to the entire RTI DCERP2 Team, SERDP, MCBCL staff, and other SERDP-funded researchers.

3.5.4 Data Analysis for Assessment of Trends

Concentrations of nutrients, carbon, CDOM, and chl *a* (benthic and water column) will be used to assess spatial patterns over the estuarine salinity gradient and seasonal trends. Statistical analyses will be conducted to determine if there are relationships between these parameters and hydrological (freshwater discharge at USGS Gum Branch Station 02093000) and meteorological data (e.g., wind, air temperature).

For each Dataflow survey, regressions will be conducted for in situ YSI chl *a* (in vivo) measurements versus laboratory analyzed chl *a* (in vitro) samples and for in situ WET Labs CDOM measurements versus CDOM absorption readings (at 440-nm wavelength; m⁻¹). These regression relationships will be used to predict extracted chl *a* (in vitro) and CDOM absorption values for each data point in a specific Dataflow survey. The empirical model of light attenuation K_d (PAR), as described by Anderson et al. (2012), will be applied to the Dataflow surveys to predict K_d (PAR) for each data point. In summary, the composite multiple linear regression model for predicting light attenuation (K_d [PAR], m⁻¹) as a function of chl *a* (extracted), turbidity (NTU), and CDOM (absorption at 440 nm) is shown in Equation 1 as follows:

$$K_d \text{ (PAR)} = 0.71 + 0.005 \times \text{chl } a + 0.066 \times \text{NTU} + 0.26 \times \text{CDOM}$$

$$(r^2 = 0.76, p < 0.001) \quad (\text{Eq. 1})$$

Maps of interpolated surface water quality and pCO₂ measurements for the shallow zone of the NRE will be made in ArcGIS 9.3 using Spatial Analyst and an inverse distance weighting technique. Using the interpolated K_d (PAR) values and NRE bathymetry (conducted by Dr. McNinch in 2009 during

DCERP1), the percentage of bottom area in the NRE receiving at least 1% of surface irradiance (defined as benthic photic area) will be determined. Variations in predicted photic area will be analyzed for statistical relationships with hydrological and meteorological data.

3.5.5 Products and Outcomes

The products of AEM-3 will include GIS maps showing spatial variations in water quality and physical parameters through the shallow areas of the estuary for time scales varying from bi-monthly to annually and inter-annually. DO data collected bi-monthly at fixed stations and following storm events will be used by Research Project AE-6 to demonstrate how the trophic state of the estuary varies through time and in response to episodic events. The DO, pCO₂, and DIC water quality data will all be provided to Research Project TSP-2 for calibrating and validating the ESM. The DOC, DIC, and pCO₂ data will contribute to the development of an NRE carbon budget by the Aquatic/Estuarine Module Team and ultimately to the development of an overall carbon budget for the estuary/coastal area when added to the coastal marshes and coastal barrier carbon budgets.

3.6 AEM-4: New River

3.6.1 Objectives

The objective of AEM-4 is to characterize the watershed inputs of carbon, nitrogen, and phosphorus into the NRE from the non-tidal portion of the New River. The concentrations of these elements will be combined with river discharge reported by the USGS to calculate elemental loads to the NRE. This effort will build on the monitoring data from DCERP1 at this site. Monitoring during DCERP2 will be conducted over a 4-year period, thus capturing a broad range of climatic variability and runoff conditions, which affect elemental loading to the estuary. An additional effort during DCERP2 will be to strategically sample both high- and low-discharge periods over the course of a year. This effort will fill an information gap regarding the differences in elemental flux during a range of river discharges. Monitoring during DCERP1 was conducted over a relatively small range of discharges relative to the annual range (**Figure 3-8**). The existing monitoring data from the non-tidal New River, therefore, do not permit examination of how changes in seasonal patterns in precipitation and runoff patterns associated with climate change or land-use change will affect the input of carbon and other elements to the NRE.

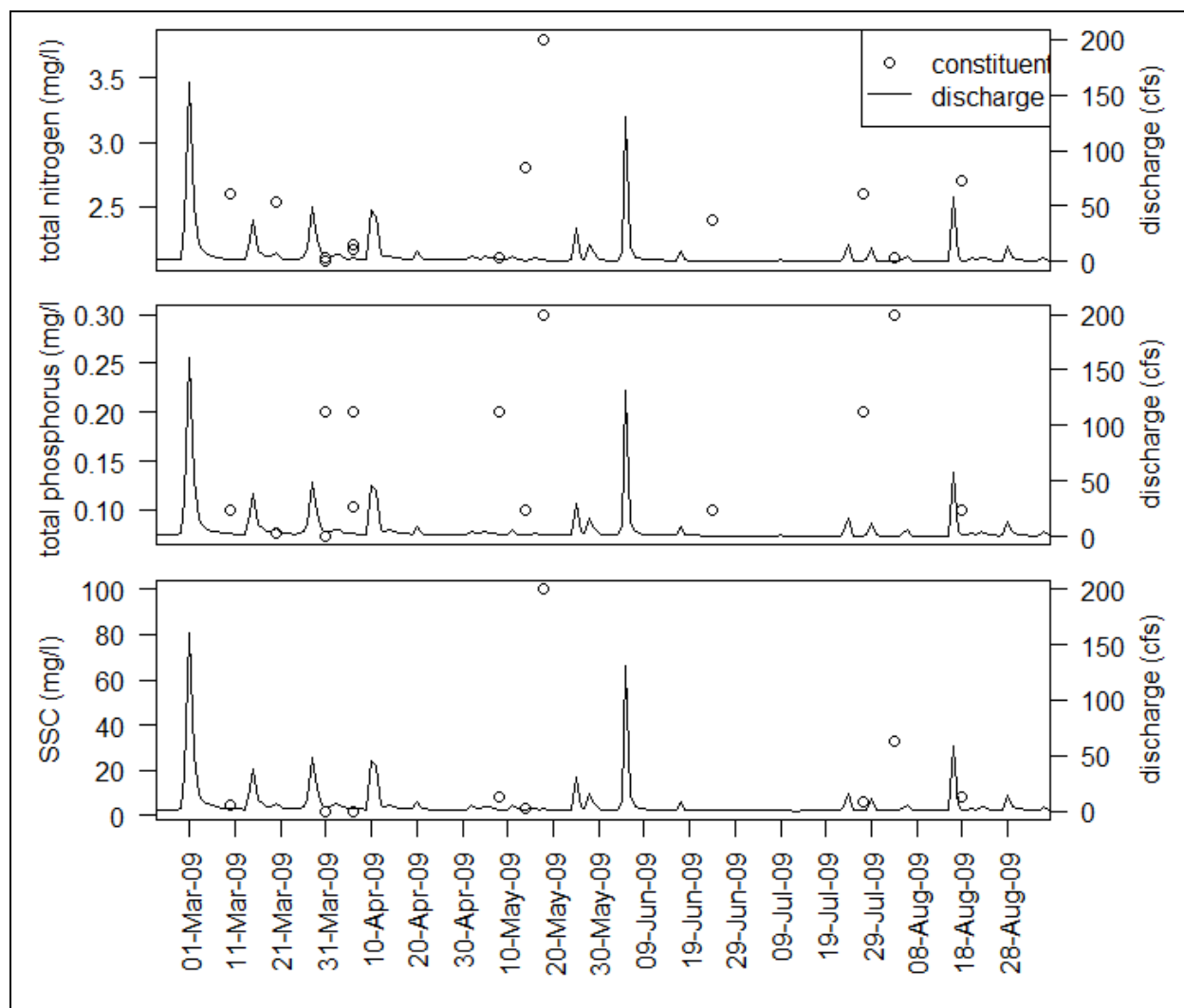


Figure 3-8. Total nitrogen, total phosphorus, and suspended sediment concentration (SSC) at the New River near Gum Branch; discharge data provided by the USGS.

During this monitoring period, no samples were collected during high-discharge events.

3.6.2 Relationship Within the Module and Among Other Modules

The time series of carbon, nitrogen, and phosphorus flux at the Gum Branch gauging station will be used to parameterize the model(s) of carbon developed in Research Project TSP-2 by Dr. Mark Brush. This carbon-based ecosystem model at the core of the DCERP2 requires input on the seasonal and inter-annual range in carbon, nitrogen, and phosphorus delivered to the New River from the watershed. AEM-4 is designed to provide these data with the most efficient sampling effort possible. The data provided by AEM-4 will also be critical for interpreting information collected by other research and monitoring components that involve sampling of aquatic and estuarine ecosystem dynamics, including AEM-1, AEM-2, and AEM-3, and Research Projects AE-4, AE-5, and AE-6. The response variables measured by these monitoring and research components (e.g., primary productivity, ecosystem respiration, watershed runoff) are either directly or indirectly associated with the parameters measured by AEM-4: fluvial nutrient flux, river discharge, and particulate flux.

3.6.3 Methods

3.6.3.1 Spatial/Site Locations

Sampling will be conducted at the New River near Gum Branch (34° 50' 57" N, 77° 31' 10" W), from the downstream side of Northwest Bridge Road. Discharge data from the USGS gauging station on the New River near Gum Branch will be downloaded by Aquatic Analysis and Consulting from the USGS's National Water Information System Web interface. The instantaneous discharge reported closest to the time of sampling will be used to calculate the instantaneous flux of carbon, nitrogen, phosphorus, and particulate constituents.

3.6.3.2 Temporal Considerations

Sampling will be conducted from 2013 through 2016 twice during the following periods: January–February, March–April, May–June, July–August, September–October, and November–December. The two sampling events during each period will be conducted during low- and high-discharge periods when possible. The contrast in discharge during each period will differ depending upon the discharge regime. During some periods, it is possible that no high-discharge events will occur, whereas in other periods, no low discharge may occur. Nevertheless, two sampling events will be conducted during each period.

3.6.3.3 Personnel

- Lead Investigator: Dr. Scott Ensign
- Supporting Researcher: Dr. Matthew McIver (general partner, Aquatic Analysis and Consulting)

3.6.3.4 Parameters and Variables

- Water temperature (°C)
- Dissolved oxygen (DO)
- Conductivity
- Chl *a* fluorescence measured following acetone extraction from glass fiber filters
- Nutrients (nitrate, ammonium, dissolved organic nitrogen [DON], total nitrogen [TN], dissolved inorganic nitrogen [DIN], phosphate)
- Carbon (dissolved inorganic carbon [DIC], particulate organic carbon [POC], and dissolved organic carbon [DOC])
- Suspended sediment concentration (SSC)

3.6.3.5 Field and Laboratory Procedures

Sampling Design and Collection

Salinity, conductivity, temperature, and DO will be measured onsite. Water samples for analysis of ammonium, nitrate + nitrite, DON, phosphate, DIC, DOC, POC, and SCC will be collected in 1-L acid-rinsed polyethylene bottles. Water samples will be returned on ice to Aquatic Analysis and Consulting, and filtered through precombusted Whatman glass fiber filters (0.7 µm). The samples will then be stored on ice until delivery to Dr. Hans Paerl at the UNC-IMS for all aqueous analytical chemistry (less than 24 hours after collection) using the same methods of analysis as those summarized in Section 3.3.1 (AEM-1). Filters will be frozen after filtration and analyzed for chl *a* fluorescence following extraction in 90% acetone.

SCC will be analyzed by Aquatic Analysis and Consulting using ASTM Method D 3977-97 (ASTM International, 1999).

Equipment Used

Field

Field equipment will include a YSI 6820 multiprobe datasonde.

Laboratory

Laboratory equipment will include a drying oven, an analytical balance, a filtration apparatus, and a Turner Trilogy Fluorometer.

3.6.3.6 Data Management

Data recorded in the field will be entered into a digital database, and the handwritten notes and two independent digital copies of the data will be maintained by Aquatic Analysis and Consulting. All digital data entry from handwritten notes will be verified. Data will be obtained from UNC-IMS at 6-month intervals in digital form. At 6-month intervals, the data output from AEM-4 will be transposed into the EDD templates as prescribed by the DCERP Data Policy and uploaded into the DCERP DIMS. The DCERP DIMS securely stores the data and makes it available to the entire RTI DCERP2 Team, SERDP, MCBCL, other SERDP-funded researchers.

3.6.4 Data Analysis for Assessment of Trends

Elemental and constituent concentrations during high- and low-discharge periods will be compared using appropriate statistical techniques for comparing variance between groups. The cumulative flux of constituents over long time scales depends upon the relationship between discharge and concentration, and identifying the contribution of various flow regimes to cumulative flux will inform the parameterization of ecosystem-based models. Statistical relationships between discharge and constituent concentration will also be investigated to determine the relative importance of season and discharge on constituent loading to the NRE (e.g., Stow and Borsuk, 2003). Time series data will be investigated for temporal trends using Seasonal Trend Decomposition using LOESS (Cleveland et al., 1990; Qian et al., 2000).

3.6.5 Products and Outcomes

AEM-4 will produce two products independent from the broader estuarine/coastal budget that it will help parameterize. The first product of AEM-4 will be a cumulative frequency distribution of elemental load based on discharge regime of the New River. This product will provide MCBCL natural resources managers and ecosystem modelers with a heuristic tool to examine how climate-related changes in river discharge may influence nutrient loading to the estuary. The second product of AEM-4 will be a time-series analysis of changes in river discharge over intra- and inter-annual cycles since the USGS began gauge operation in 1950. Long-term changes in seasonal patterns in discharge variation may provide insight on how climate-related changes in rainfall and temperature have influenced estuarine inputs of carbon and other elements. This time-series analysis may be combined with the cumulative frequency distribution of elemental flux to examine how elemental loading has changed over time and to predict how elemental loads may change in the future in response to changes in discharge regime; this analysis will be completed before 2017.

4.0 Coastal Wetlands Module

The following subsections of this section contain the proposed monitoring activities for the Coastal Wetlands Module, including background information on the module, the knowledge gaps in the conceptual model that the monitoring data will fill, and the individual monitoring activities that are proposed for implementation. Specific information is provided for each activity, such as its objectives and

methods and the relationships of the monitoring activities of the Coastal Wetlands Module to the Coastal Wetlands research projects and to other modules.

4.1 Introduction

Coastal marshes are a vital component of the estuarine landscape and link terrestrial and freshwater habitats with the sea (Levin et al., 2001). These interactions include the exchange of solutes, including carbon and nutrients (Cai, 2011; Jordan et al., 1983); fauna; and sediment. In the intertidal zone, marshes help to stabilize sediments and minimize erosion (Gedan et al., 2011; Knutson et al., 1982; Möller et al., 1999). Wetlands improve water quality by acting as nutrient transformers and by trapping sediment (Harrison and Bloom, 1977; Morris, 1991; Valiela and Teal, 1979). Generally speaking, marshes consume (denitrify) nitrate dissolved in flood water and, thus, have a beneficial effect on estuarine water quality. In addition, coastal wetlands provide critical habitat area for a diverse group of estuarine organisms, serve as nursery habitat for commercially important fishery species (Kneib, 1997), and provide recreational opportunities for people.

Salt marshes also play an important role in the global carbon cycle. Recent estimates suggest that some coastal habitats store more carbon per area and take up more carbon annually than terrestrial habitats (Nellemann et al., 2009). As a result, these coastal habitats, even though they account for a small percentage of land cover, are approximately an equivalent carbon sink as other major terrestrial habitats, including temperate, tropical, and boreal forests (McLeod et al., 2011; Nellemann et al., 2009). However, across the United States, coastal salt marshes have declined in area over the past 200 years, and they are currently being lost at a higher rate than any other wetland category (Dahl, 2011). The majority of this loss results from the conversion of salt marsh to open water and is a result of sea level rise, storm events, erosion, and changes in land-use practices (Cahoon et al., 2006; Kirwan and Blum, 2011; Mattheus et al., 2010; Morris et al., 2002). Projected acceleration in sea level rise (Bindoff et al., 2007; Vermeer and Rhamstorf, 2009) will exacerbate these processes and will require both improved modeling efforts and adaptive management approaches to minimize the adverse impact of marsh loss on coastal ecosystems.

Figure 4-1 presents the conceptual model for the Coastal Wetlands Module, illustrating the complementary nature of critical estuarine physical, chemical, and biotic processes and interactions. Integration of the marsh–barrier island is crucial because marshes provide a platform over which the barrier dune system can migrate, and the dunes protect the marshes from erosive wave energy that would otherwise degrade them. Along the estuarine shoreline, marshes protect uplands from flooding and storm surge. The marshes will also migrate over the terrestrial landscape in response to rising sea level where the topography allows. Exchanges of sediment and organic and inorganic carbon with estuarine waters occur (via diffusion and settling) when the marsh is submerged. Exchange of carbon with the atmosphere and estuarine waters (via diffusive flux to the atmosphere and advective exchange of marsh porewater) can occur during emergent periods. Marsh primary production that is not decomposed and lost to the atmosphere or estuary can be buried through sediment accretion and net surface elevation increase, and this represents a net carbon sink to the ecosystem.



Figure 4-1. Conceptual model for the Coastal Wetlands Module.

The monitoring activities and research projects of the Coastal Wetlands Module have been designed as an integrated program. These activities include measuring surface elevation of marshes, tracking changes in vegetation density and species distribution over time, measuring shoreline position, and monitoring water level. The stations established for the monitoring activities are used by the research projects of this module to determine the response of the coastal marsh to sea-level rise and evaluate the impacts of inundation, erosion, and vegetation on marsh carbon flux and burial rates. As new understanding of these ecosystem processes and stressors is gained during the course of DCERP2 research, the module-level conceptual model will be revised based on this new information.

4.2 Coastal Wetlands Module Objectives and Activities

The Coastal Wetlands Monitoring Program (CWMP) is designed to (1) improve understanding of the physical, biological, and ecological processes that determine the stability and community structure of the coastal wetlands ecosystem; (2) quantify spatial and temporal (inter-annual) variability in key parameters affecting marsh carbon, nutrient, and sediment fluxes; (3) provide data to support development of forecasting tools and models; and (4) use these tools to guide adaptive management actions to improve the sustainability of coastal wetlands to climate change and man-made impacts. Specific variables include those that characterize the system at the plant-community structure level, landscape-scale measures of marsh geomorphology, and tide and water quality data to assess hydrodynamic features that shape the

landscape. The CWMP data are used by Research Projects AE-4, AE-6, CW-4, CW-5, and CB-5, and provide input to the ESM being refined as part of Research Project TSP-2.

Coastal wetlands on MCBCL include backbarrier island marshes that are crucial to island dynamics, *Spartina alterniflora*–dominated marshes adjacent to both Browns and the New River Inlets and along the ICW, and fringing marshes in embayments and tributaries of the mainstem NRE, which transition from *Spartina*-dominated in the lower estuary to *Juncus roemerianus*–dominated in the mid-estuary. However, the distribution and productivity of marsh vegetation varies along elevation, nutrient, and salinity gradients and is sensitive to annual variations in rainfall and sea level (Pennings and Bertness, 2001). Furthermore, tidal dynamics and wave energy exert significant controls on the shape of the marsh landscape, as well as its response to short- and long-term changes in sea level (Friedrichs and Perry, 2001; Kolker et al., 2009). The CWMP strategy is to (1) measure forcing factors affecting marsh distribution, production, and erosion/accretion; and (2) document annual variability in marsh production and sedimentation rates across landscape-scale gradients in elevation, tidal amplitude, and wave exposure (Table 4-1).

Table 4-1. Components of the Coastal Wetlands Monitoring Program

Component	Variable	Temporal Scale	Spatial Scale	Method	Team Lead ^a
CWM-1	Shoreline erosion	Every 2–3 years	6 stations	RTK-GPS, DEM	CC
	Marsh surface elevation change	Quarterly and episodic events	16 SETs at 6 stations	SETs	
	Marsh vegetation and snails	Annually	Permanent 1 m ² plots, 15–24 plots per site, 6 sites	Stem density, stem height, and percent cover; density of <i>Littorina irrorata</i>	
	Water level, temperature, salinity	Continuous (every 6 minutes)	2 stations	Tide gauges	

Note: DEM = Digital Elevation Model; RTK-GPS = real-time kinematic global positioning system; SET = surface elevation table.

^a CC = Carolyn Currin.

4.3 CWM-1: Coastal Wetlands

4.3.1 Objectives

The Coastal Wetlands Module monitoring effort is designed to provide data to support the module's research objectives, parameterize model efforts, provide observations to test model predictions, and quantify spatial and temporal variability in factors controlling marsh carbon fluxes. Specific objectives of Coastal Wetlands Module monitoring include the following:

- Determining the net change in surface elevation across the estuarine tidal and salinity gradient in MCBCL marshes
- Measuring sediment accretion rates across the estuarine tidal and salinity gradient in MCBCL marshes
- Determining inter-annual variability in marsh above-ground biomass and species composition
- Measuring temporal and spatial variability in snail density of MCBCL marshes and determining the relationship to marsh above-ground biomass
- Estimating the volume of eroded marsh shoreline to support an estuarine carbon budget

- Providing tide gauge data in the lower and upper portions of the NRE to support hydrodynamic models and inundation calculations and to assess the impact of storm events.

4.3.2 Relationships Within the Module and Among Other Modules

Research Project CWM-1 will collect the data necessary for conducting trend analysis and for distinguishing relative impacts of acute (event-scale), seasonal and longer term scales of external and internal drivers on ecosystem biogeochemical and trophic responses. These data will also be used for spatially and temporally “scaling up” and filling technical and conceptual information gaps for Research Projects CW-4 and CW-5 and for developing and validating of a marsh model and provide input for refining the ESM (Research Project TSP-2) to be performed during DCERP2. Data obtained during Research Project CWM-1 will be highly complementary to and integrated with Research Project CW-4. Research Project CWM-1 provides the empirical foundation for Research Projects CW-4, CW-5, and CB-5. Lastly, Research Project CWM-1 will provide information to better understand the context in which complex interacting physical, chemical, and biotic processes drive marsh growth (above-ground biomass production), species composition, and accretion under varying tidal and salinity gradients; measure the temporal and spatial variability between snail density and marsh above-ground biomass; and estimate the volume of eroded marsh shoreline to support the development of a carbon budget for the marsh as part of Research Projects CW-4 and CW-5.

4.3.3 Methods

4.3.3.1 Spatial/Site Locations

The coastal wetlands that are the focus of this module are defined as the vegetated inter-tidal habitat in salt and brackish waters and include the salt marshes along the lower NRE shoreline and ICW to the brackish marshes along the upper NRE shoreline and tributaries of the NRE. These areas within the MCBCL region are typically dominated by smooth cordgrass (*Spartina alterniflora*) and black needle rush (*Juncus roemerianus*). The monitoring stations are stratified along the salinity and tidal gradient and include wetlands in both the NRE and ICW (**Figure 4-2** and **Table 4-2**).

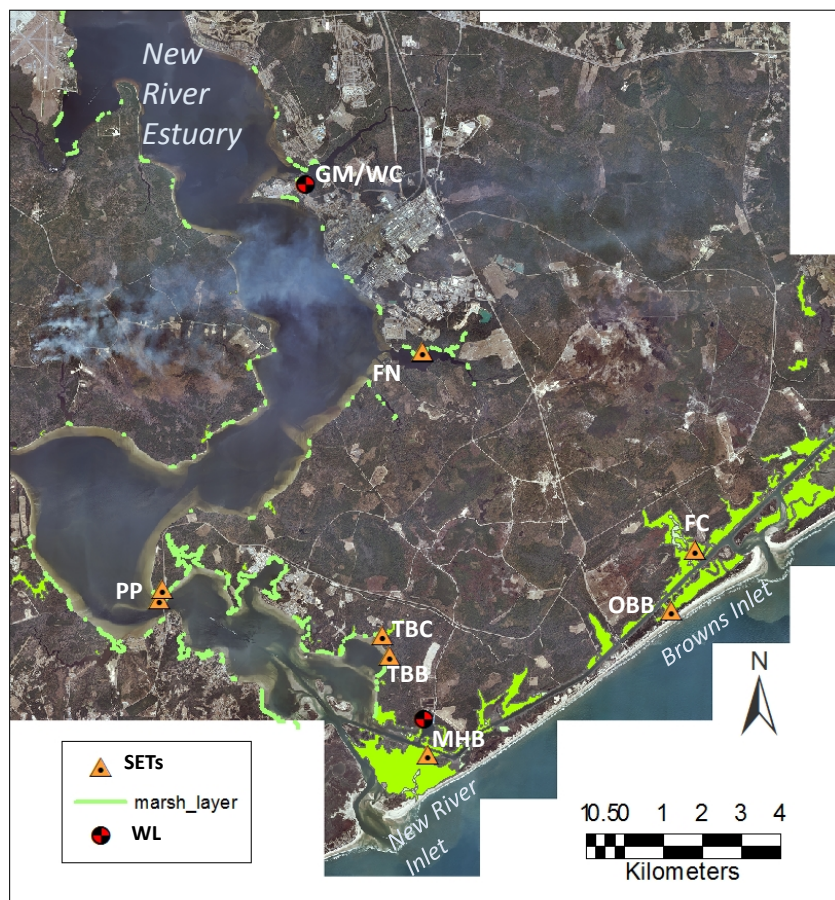


Figure 4-2. A map of the coastal wetlands on MCBCL (green) and the locations of monitoring stations.

Location of surface elevation tables (SETs; orange triangles) and temporary tide gauge (WL) stations (red and black circles) are indicated by symbols and site codes. Monitoring site names and their respective abbreviation IDs are provided in **Table 4-2**.

Table 4-2. Sampling Stations and Parameters for the Coastal Wetlands Monitoring Program

Surface elevation tables (SETs) will be used to measure surface elevation, and marker horizons (MHs) will be used to measure sediment accretion rates. Water level (WL) will be measured using logging pressure sensors, and Digital Elevation Models (DEMs) will be obtained with 2 cm accuracy using RTK-GPS receivers.

Site/Station	ID	Parameter	Sample Frequency	Sampling Duration	Sampling Notes
Gottschalk Marina/Wallace Creek	GM/WC	Water level, temperature, salinity	Continuous	2013–2017	YSI 600 LS datasondes surveyed to benchmarks
French Creek • Shore • Upper	FN	Surface elevation	Quarterly	2013–2017	SETs (2)
	FNS	Sediment accretion	Quarterly	2015–2017	MH
	FNU	Vegetation/snail density	Annually	2013–2017	Permanent plots
		Vegetation biomass	Annually	2015–2016	Permanent plots
		Water level	Continuous	2013–2017	WL loggers
		Shore erosion	Biannual	2014–2016	DEM

(continued)

Table 4-2. Sampling stations and parameters for the Coastal Wetlands Monitoring Program (continued)

Site/Station	ID	Parameter	Sample Frequency	Sampling Duration	Sampling Notes
Pollocks Point • Shore • Upper	PP PPS PPU	Surface elevation	Quarterly	2013–2017	SETs (2)
		Sediment accretion	Quarterly	2015–2017	MH
		Vegetation/snail density	Annually	2013–2017	Permanent plots
		Vegetation biomass	Annually	2015–2016	Permanent plots
		Shore erosion	Biannual	2013–2016	DEM
Traps Bay • Bridge • Creek	TB TBB TBC	Surface elevation	Quarterly	2013–2017	SETs (2)
		Sediment accretion	Quarterly	2015–2017	MH
		Vegetation/snail density	Annually	2013–2017	Permanent plots
		Vegetation biomass	Annually	2015–2016	Permanent plots
		Water level	Continuous	2013–2017	WL loggers
		Shore erosion	Biannual	2014–2016	DEM
Mile Hammock Bay • Control • Fertilized	MHB MHBC MHBF	Water level, temperature, salinity	Continuous	2013–2017	YSI 600 LS datasondes
		Surface elevation	Quarterly	2013–2017	SETs (2)
		Sediment accretion	Quarterly	2013–2014	MH
		Vegetation/snail density	Annually	2013–2017	Permanent plots
		Vegetation biomass	Annually	2014–2016	Permanent plots
		Shore erosion	Biannual	2013–2017	DEM
Onslow Backbarrier • Control • Fertilized	OBB OBBC OBBF	Surface elevation	Quarterly	2013–2017	SETs (2)
		Sediment accretion	Quarterly	2013–2014	MH
		Vegetation/snail density	Annually	2013–2017	Permanent plots
		Vegetation biomass	Annually	2013–2017	Permanent plots
Freeman Creek • Control • Fertilized	FC FCC FCF	Surface elevation	Quarterly	2013–2017	SETs (2)
		Sediment accretion	Quarterly	2013–2014	MH
		Vegetation/snail density	Annually	2013–2017	Permanent plots
		Vegetation biomass	Annually	2013–2014	Permanent plots
		Water level	Continuous	2013–2014	WL loggers

4.3.3.2 Temporal Considerations

Temporary tide gauges at two stations (Gottschalk Marina/Wallace Creek and Mile Hammock Bay) will continue to collect water level, temperature, and salinity data at 6-minute intervals, which is the sampling frequency required to calculate tidal datums. The data will be collected throughout the DCERP2 study period, providing an unbroken record since datasondes were initially deployed in 2008.

Surface elevation table (SET) data will be collected quarterly at all stations throughout DCERP2. Additional SET readings may be obtained before and after storm events. Marker horizon data will be collected at quarterly intervals in conjunction with SET readings, but will not be collected throughout DCERP2 at each SET. Instead, marker horizon readings will be obtained in *Spartina*-dominate marshes during 2013 and 2014, and in *Juncus*-dominated marshes in 2015 and 2016. SET and marker horizon readings are typically obtained from all stations within a 1-week period, weather permitting.

Vegetation percent cover, species composition, stem density (*Spartina*) or above-ground biomass (*Juncus*), and snail (*Littorina irrorata*) density will be collected annually during July–August at the time of peak marsh biomass at each station. It is important to capture the peak biomass data within a relatively narrow window of time (30 days) to statistically compare results among stations and over time. Weather permitting, these collections will be completed within 30 days at all stations.

Above-ground *Spartina* biomass data will be collected concurrently with percent cover and stem density measurements during 2013 and 2014. This activity will take place during the performance of concurrent Research Project CW-4 activities to determine the ratio of above-ground:below-ground biomass across the elevation gradient in MCBCL marshes.

Digital Elevation Models (DEMs) to calculate shoreline erosion will be collected on two occasions at each of the shoreline sites. The resolution of this technique is approximately 2 cm and provides an estimate of both horizontal change of a specific elevation (e.g., 0.00 m North American Vertical Datum of 1988 [NAVD 88]) and an estimate of the change in volume of the shoreline. Baseline measurements for all stations were obtained during DCERP1, and given the average erosion rate of marsh shorelines, a period of 2–3 years is required to detect change using this approach.

4.3.3.3 Personnel

- Lead Investigator: Dr. Carolyn Currin
- Technicians: Mr. Michael Greene, Ms. Anna Hilting, and one Technician
- Contractor: GeoDynamics

4.3.3.4 Parameters and Variables

- Shoreline erosion (m y^{-1} , $\text{m}^3 \text{y}^{-1}$)
- Marsh surface elevation change (mm y^{-1})
- Marsh sediment accretion rate (mm y^{-1})
- Marsh vegetation (stem density, stem height, percent cover) (number m^{-2} , cm, %)
- Grazer (snails) density (number/m^2)
- Water level (m NAVD 88)
- Water temperature ($^{\circ}\text{C}$)
- Salinity (ppt)

4.3.3.5 Field and Laboratory Procedures

Marsh Vegetation Composition and Biomass

Permanent 1- m^2 plots will be established within the marsh area surrounding the SETs at each station. Sampling plots established in DCERP1 with a restricted random sampling approach will be incorporated where possible into DCERP2 vegetation sampling, but will not be identical in all cases. DCERP2 plots will be selected to provide 3–5 replicate plots within 10-cm elevation intervals at each site, across the range of marsh elevations at each site. This will vary with tidal amplitude (McKee and Patrick, 1988) and will result in between 15 and 25 plots per site. In each plot, plant species and percent cover will be visually estimated according to the Carolina Vegetation Survey categories (Peet et al., 1998). Live and dead stem densities for *Spartina alterniflora* will be measured in 0.25- m^2 subplots, and 10 *Spartina* stem heights along a mid-plot transect will be recorded. *Spartina alterniflora* stem height and stem density data will be used to estimate biomass (grams dry weight per m^2) with a regression model. Destructive harvests for the ratio of above-ground:below-ground biomass collection as part of Research Project CW-4 will be compared to estimated monitoring data. The numbers of the gastropod, *Littorina irrorata* (marsh

periwinkle), will be recorded from each plot. Elevation at each plot will be obtained using RTK-GPS technology and/or laser leveling to an accuracy of 2 cm (see below).

Benchmark and Surface Elevation

Using standard National Geodetic Survey (NGS) protocols, we obtained an elevation for at least one SET at each of the marsh sites and at each tide gauge site by obtaining at least three independent Online Positioning User Service (OPUS) solutions using RTK-GPS. The installation of a SET, in combination with the use of RTK-GPS technology and OPUS post-processing of data, effectively provide a tidal benchmark that can be used in perpetuity as a reference point for elevation surveys. The overall accuracy of these elevation measures has been improved to 2 cm with the recent completion of a Height Modernization campaign, in collaboration with North Carolina Geodetic Survey (details on NOAA's Height Modernization Program are available at <http://www.ngs.noaa.gov/heightmod/Definition.shtml>). These reference points are especially valuable in relatively remote locations within the estuarine intertidal areas because they enable the preparation of DEMs for each site and improve our ability to detect elevation change and a shift in horizontal position of shorelines. DEMs are developed using Trimble R6 dual-phase receivers in real-time kinematic mode, and a rover unit is used to collect topographic data in a real-time environment. This is accomplished by a radio link to a base station that receives real-time corrections via satellite from Continuously Operating Reference Stations (CORS). Data are transferred to ArcGIS using the Trimble Geomatics Office software. In ArcGIS, point data are displayed and edited for any anomalies. Using the Arc Tools, natural neighbor selection, point data are displayed as a DEM grid raster.

DCERP1 results demonstrated that the accretion of mineral sediments on the marsh surface exceeds the net surface elevation change by 1.5 to 3 times, in both *Spartina*- and *Juncus*-dominated marshes. Part of this discrepancy could be due to local subsidence, which has been estimated at 0.8 to 1.0 mm y⁻¹ (Engelhart et al., 2009; Kemp et al., 2011), and so could contribute up to 25% of the observed difference in sediment accretion rates. The SET mark elevation data gathered as part of this monitoring program are not expected to have the resolution to detect local subsidence. We will rely on other calculations of local subsidence such as those based on NOAA's National Geodetic Survey CORS and long-term tidal data.

Water Level/Tide Gauge

NOAA's Beaufort Laboratory established water-level stations at Mile Hammock Bay on February 21, 2008, and at Gottschalk Marina on May 15, 2008, following protocols established in conjunction with the Center for Operational Oceanographic Products and Services (CO-OPS; NOAA, 2007a). At each station, a vented datasonde (YSI Model 600LS) was deployed at a stable elevation, which was measured precisely to a physical reference point on the supporting structure. The datasondes record water level, temperature, and salinity every 6 minutes. Data are downloaded at least every 2 months, and datasondes are replaced every 3 to 6 months. The datasondes undergo calibration procedures prior to and after deployment to test for drift and data quality.

Water levels have been corrected to NAVD 88, using OPUS observations following protocols established by NOAA's NGS. Datasonde sensor NAVD 88 elevations are derived using the NGS OPUS, virtual reference stations global positioning systems (VRS GPS), and RTK-GPS technology, as well as laser-leveling techniques modified from the *User's Guide for Installation of Bench Marks and Leveling Requirements for Water Level Stations* (NOAA, 1987), *NGS-58 Guidelines for Establishing GPS-Derived Ellipsoid Heights* (NOAA, 1997), and NOAA CO-OPS' *Users Guide for GPS Observations* (NOAA, 2007b). Datasondes are referenced to at least three reference marks near the tide station. Data have been provided to NOAA CO-OPS for QA and QC checks and data analysis of water-level data to determine local tidal datum (NOAA, 2007a). NOAA's CO-OPS and NOAA's CCFHR staff will use the local observations to conduct inundation analysis of the NRE marshes.

SETs and Marker Horizons

SETs and feldspar marker horizons were established at marsh sites in 2008. The sediment elevation associated with each SET is obtained by measuring the distance (in millimeters) between the SET arm and sediment surface with 36 pins. SET readings are taken every 1 to 3 months, following the method described by Cahoon et al. (2002). At each SET sampling time, three 0.25-m² marker horizon plots are established with feldspar. Marker horizon readings are taken at the subsequent SET reading by removing small cores of sediment obtained with liquid nitrogen to minimize compaction. Digital calipers are used to measure the distance between the feldspar layer and sediment surface.

Equipment Used

Field

The field equipment includes YSI 600 LS vented datasondes, a Trimble R6 RTK GPS dual-phase receiver, a CST Berger LaserMark 400, digital calipers, and a SET.

Laboratory

The laboratory equipment includes a drying oven, ashing ovens, balances, and a Perkin Elmer CHN analyzer.

4.3.3.6 Data Management

Data recorded in the field are copied immediately and duplicates stored in a safe. Data are entered into spreadsheets (Microsoft Access or Excel) and proofed. Master files are maintained, which include all vegetation, grazer, SET, and marker horizon data. Water-level data from YSIs are downloaded monthly and post-calibrated when datasondes are swapped out every 3–4 months. GPS and GIS data are post-processed as necessary and saved in geodatabases. All NOAA data are saved on laboratory network servers, which are backed up daily. At 6-month intervals, the data output from Research Project CWM-1 will be transposed into the EDD templates as prescribed by the DCERP Data Policy and uploaded into the DCERP DIMS. The DCERP DIMS securely stores the data and makes it available to the entire RTI DCERP2 Team, SERDP, MCBCL, other SERDP-funded researchers.

4.3.4 Data Analysis for Assessment of Trends

Rates of marsh surface elevation change and sediment accretion will be evaluated with linear regression. Inter-annual variability and the relationships between plot elevation, vegetation, and snail density are determined with the SAS Proc Mixed and Repeated Measures (SAS Institute Inc., 2004). We will scale the monitoring data to whole-marsh estimates. To support that effort, we will be collecting the model parameters (e.g., marsh biomass, carbon flux measures, sediment accretion) across a range of surface elevations at locations with different tidal amplitudes, which will support “scaling-up” efforts.

4.3.5 Products and Outcomes

Tide gauge data will be used to determine marsh inundation, quantify seasonal changes in average water level, and measure the impact of storm events (wind and precipitation) on water level, temperature, and salinity. These data will inform hydrological modeling and the ESM being refined as part of Research Project TSP-2.

SET and marker horizon data will provide input into Research Project CW-4 models on marsh response to sea level rise and for calculating carbon burial rates. Research Project CW-4 will be scaling the monitoring data from whole-marsh estimates. To support that activity, we will be collecting the model

parameters (marsh biomass, carbon flux measures, sediment accretion) across a range of surface elevations at locations with different tidal amplitudes, which will support “scaling-up” efforts.

Monitoring of vegetation distribution and biomass will provide input into marsh models developed by Research Project CW-4 and will help in developing the marsh carbon budget. Monitoring data will provide information on the relationship between an important marsh grazer (snails) and above-ground biomass. Maps and GIS layers of marsh DEMs and shoreline erosion rates will be developed to inform assessment of vulnerable coastal wetlands and provide guidance for adaptive management approaches.

5.0 DCERP Data Management

Environmental data collected throughout the duration of the program are critical to DCERP research and modeling activities and to the development of decision-support management tools. In support of DCERP1, the Data Management Module developed the DIMS and procedures to manage the data and to enable efficient, secure, and accurate input, analysis, integration, display, and sharing of data. Data integration, sharing, and management are key functions of the DIMS that will continue into DCERP2. Web-based access and interfaces allow the RTI DCERP researchers, MCBCL staff, and other users to access DCERP data from MARDIS. The DIMS also makes DCERP information available to the general public via the DCERP public Web site, provides a secure password-protected Web site for team collaboration, and supports the data management needs of DCERP2, including data archiving, searching, and retrieval. The DIMS consists of several distinct systems as shown in **Figure 5-1**.

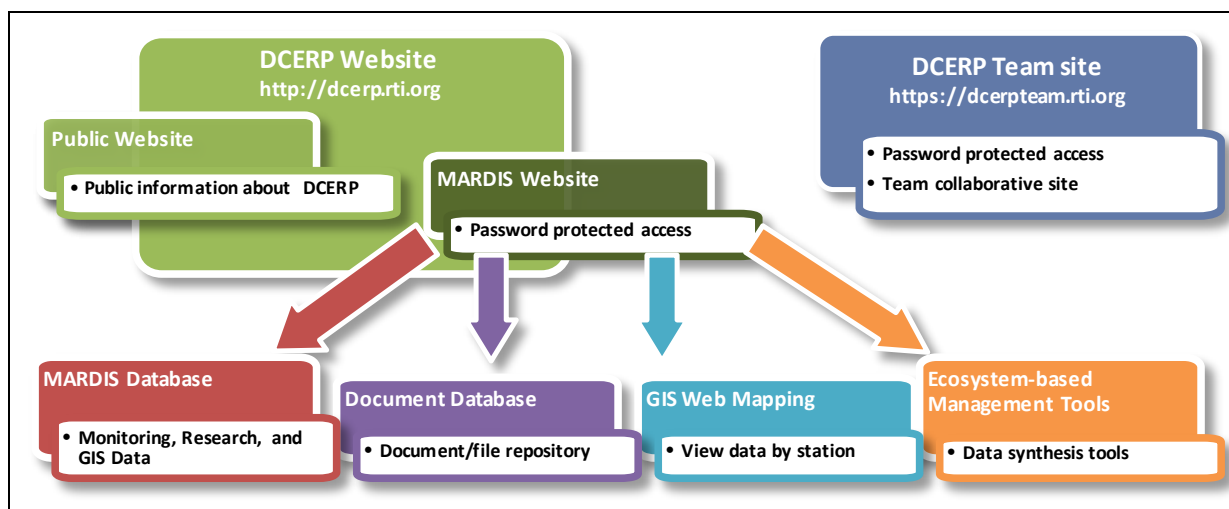


Figure 5-1. DCERP DIMS.

The DCERP program developed and will continue to abide by the DCERP Data Policy (see **Appendix A** of this *DCERP2 Monitoring Plan*). DCERP data are made available to authorized users via access to MARDIS. In this way, all data are easily searched via the Web. When possible, DCERP monitoring data will be available in MARDIS within 6 months of collection, and research data will be available within 2 years of the data collection date. After these dates, the data will be available to the broader community for academic, research, educational, government, or other not-for-profit professional purposes. Varying levels of data access have been implemented in the DCERP DIMS via user groups and roles to prevent unauthorized access to sensitive information or compromising data quality. DCERP researchers are responsible for processing raw monitoring data results (e.g., laboratory and field results) into the templates for loading into MARDIS. The researchers are also responsible for conducting the QA and QC procedures on data they have collected. The MARDIS upload mechanism provides basic validation

checks to ensure that, where possible, data values that are invalid or out of range are detected prior to loading. For more information on DCERP Data Management, see the *DCERP2 Research Plan*.

6.0 Measurements of Success

Measurement of DCERP's success will come from assessing whether the desired outcomes are achieved, and whether the outcomes are produced in a timely manner. The outcomes defined for DCERP2 can be grouped into three main categories, programmatic, research specific and monitoring specific.

Programmatic and research-specific measures of success are described in the *DCERP2 Research Plan*.

Monitoring-specific measures of success are defined as follows and are detailed in **Table 6-1**.

- **Monitoring specific**—This category includes those outcomes resulting directly from the monitoring efforts of the Aquatic/Estuarine and Coastal Wetland Modules. In some cases, these outcomes provide information to address environmental issues that are currently impacting installation operations or may impact installation operations under projected climate change scenarios. In addition, the majority of the DCERP2 monitoring activities will provide the information necessary to gain a comprehensive understanding of ecosystem functions, including carbon cycling, nutrient cycling, and sediment transport, which will better prepare DoD to address future environmental issues under changed climate conditions. Key outcomes and products that are anticipated to result from each monitoring activity are described in Sections 3.0 and 4.0 of this *DCERP2 Monitoring Plan*.

Table 6-1. Timeline for monitoring-specific outcomes

Product/Activity/Outcome	Due Date
Prepare peer-reviewed journal articles and conference presentations—Present key scientific results to other researchers at national and international scientific meetings	Beginning in 2014
Develop a carbon budget for the estuarine/coastal area of MCBCL	March 2015 (draft) March 2017 (final)
Advance scientific methods or knowledge relating to the measurement of carbon sources, flux, and sinks in estuarine/coastal systems	November 2017
Perform trend analysis and apply other statistical analysis techniques to evaluate monitoring data and assess the adequacy of the temporal and spatial aspects of the monitoring program	February 2014, February 2015, February 2016, and November 2017
Archive all monitoring data in MARDIS semi-annually through the end of the program	November 2017
Transition most important aspects of the monitoring program to MCBCL at the end of the DCERP2 program including parameters to be monitored, the temporal and spatial aspects of the monitoring design, appropriate field collection methods, and data analysis procedures.	November 2017

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Appendix A

DCERP Data Policy

Defense Coastal/Estuarine Research Program (DCERP)

SERDP SI-1413

DCERP Data Policy Version 1.0

November 13, 2009



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Appendix

A.	Data Use Agreement	A-1
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Definitions

Data Requestor/User—For the purposes of this document, data requestor and data user are often used interchangeably depending on context.

DCERP (Defense Coastal/Estuarine Research Program)—This program is a Strategic Environmental Research and Development Program (SERDP)—funded study sited at Marine Corps Base Camp Lejeune (MCBCL). The objective of DCERP is to study the structure, composition, and function of the major ecosystems and to assist the Base in sustaining military training and testing using ecosystem-based management techniques.

DIMS (Data and Information Management System)—The DCERP DIMS is a comprehensive data and information management system that supports and provides a permanent repository for DCERP's collection and storage of environmental data. The DIMS supports DCERP's geospatial data management, statistical analysis, model integration, document sharing, and collaboration among the DCERP Team members. The DCERP DIMS consists of the following systems: the Monitoring and Research Data Information System (MARDIS), the DCERP Web sites (i.e., the private collaborative, public, and MARDIS), the Document Database, geographical information systems (GIS) Web-mapping application, and ecosystem-based management tools.

DMM (Data Management Module)—The DCERP Data Management Module Team members administer and manage the DCERP DIMS and are responsible for DCERP data and information management.

EDD (Electronic Data Deliverable)—The EDD is a required, standard template used by all DCERP researchers for submitting data to MARDIS.

MARDIS (Monitoring and Research Data Information System)—MARDIS is the long-term repository for all DCERP monitoring and research data.

MCBCL (Marine Corps Base Camp Lejeune)—MCBCL, which is located in Jacksonville, NC, is the largest U.S. Marine Corps installation on the East Coast, and the Base serves as the host site for DCERP.

Module Team—DCERP is subdivided into five ecosystem modules and the Data Management Module to facilitate an understanding of ecosystem dynamics in the MCBCL region.

Monitoring Data—This refers to all data collected under activities specified in the *DCERP Baseline Monitoring Plan* (RTI, 2007a) or added by supplemental funding requests as new monitoring activities.

Research Data—This refers to all data collected under research project activities specified in the *DCERP Research Plan* (RTI, 2007b) or added by supplemental funding requests as new research projects.

RTI DCERP Team/Researchers—The RTI DCERP Team includes the DCERP Principal Investigator, other environmental scientists from RTI, and researchers from the University of North Carolina at Chapel Hill's Institute of Marine Sciences; North Carolina State University; the University of Connecticut; Duke University; the Virginia Institute of Marine Science; Virginia Tech; the University of South Carolina; the National Oceanic and Atmospheric Administration; the U.S. Geological Survey; the U.S. Army Corps of Engineers; Atmospheric Research and Analysis, Inc.; and Porter Scientific, Inc.

SERDP (Strategic Environmental Research and Development Program)—This environmental research and development program is planned and executed by the U.S. Department of Defense in partnership with the U.S. Department of Energy and the U.S. Environmental Protection Agency that funds DCERP and oversees the program's development.

1.0 Introduction

The data management strategy for the Defense Coastal/Estuarine Research Program (DCERP) is designed to address the needs of the program, individual DCERP researchers, Marine Corps Base Camp Lejeune (MCBCL), the larger scientific community, and other stakeholders. Central to this strategy is the timely submission and sharing of all data and metadata collected in both the monitoring and research programs. Rapid dissemination of the data and metadata will maximize information transfer and encourage integration of science, coordination of research, and the construction and testing of hypotheses. DCERP researchers have a strong commitment to data integrity and to meeting the data management requirements established by the Strategic Environmental Research and Development Program (SERDP) for storing and sharing this data with MCBCL, the scientific community, and other stakeholders.

To facilitate data management, the DCERP Data and Information Management System (DIMS) was implemented by the Data Management Module (DMM). There are two objectives of the DMM. The first objective is to support the data collection and research efforts of DCERP that better enable DCERP researchers to communicate, collaborate, and contribute to DCERP objectives. The second objective of the DMM is to make DCERP data readily available and usable by MCBCL staff to support MCBCL's long-term, ecosystem-based data-management needs (see the *DCERP Strategic Plan* [RTI, 2007c] for more information about DCERP's objectives and MCBCL's needs). The DIMS will ensure that DCERP data are readily accessible via the Monitoring and Research Data Information System (MARDIS), which is a centralized database that stores and presents data-collection activities from each ecosystem Module Team in a consistent format and standardized structure. Ultimately, all data and metadata collected under DCERP will be permanently archived in MARDIS.

1.1 Purpose

The purpose of the DCERP Data Policy is to encourage openness and sharing of DCERP data for the mutual benefit of SERDP, DCERP, MCBCL, the scientific community, and other stakeholders, while protecting the publication rights of the DCERP researchers. This policy establishes responsibilities for the timely release of data, with the understanding that some data require lengthy analytical or data-reduction procedures, as well as quality assurance/quality control (QA/QC) procedures that prevent the immediate release of data after collection. This document also specifies the general roles, responsibilities, and rights of the DMM, the DCERP researchers, and the various data users regarding the use of DCERP data and describes in full the data access, data release, and Data Use Agreements of all parties.

2.0 Data Management Responsibilities

2.1 Responsibilities of the Data Management Module

The DMM is responsible for providing and maintaining the DCERP DIMS and MARDIS Web-based data systems that hold and archive the DCERP data. The DMM develops and implements policies, guidelines, standards, and procedures for DCERP data management activities, thus ensuring the integrity, security, accessibility, and usefulness of data and information maintained in DIMS and MARDIS. The DMM ensures that data are maintained in a secure environment and are suitably controlled to assure that only authorized users can access the data. The DMM defines data standards that allow for data integration and standardization across the various types of DCERP information and works with the DCERP researchers to provide them with appropriate Electronic Data Deliverable (EDD) templates that standardize data for uploading into MARDIS. Although DCERP researchers have primary responsibility for data quality, the DMM provides basic validation checks of all data to comply with MARDIS standards and ensure data integrity. The DMM provides Web-based user interfaces that will allow authorized users to view and download data and information using various criteria, including (but not limited to) time, location,

parameter, or data set. Finally, the DMM serves as the liaison with the DCERP researchers, the DCERP On-Site Coordinator, MCBCL, and SERDP to encourage and evaluate feedback, ensure that user community needs are being met, and ensure that all levels of data and metadata are available in the appropriate time frame.

2.2 Responsibilities of the DCERP Researchers

DCERP researchers are responsible for the timely submission of all data and metadata collected during monitoring activities and research projects to MARDIS. Monitoring data and metadata should be submitted to MARDIS within 6 months of collection. Data sets that require more lengthy analytical and/or processing procedures should be submitted when they are completed. Historical data (i.e., data collected prior to the inception of DCERP) with broad value to the DCERP Team should also be submitted for archiving in MARDIS. Research data will be submitted to MARDIS no later than 2 years after collection. However, DCERP researchers are encouraged to submit research data and metadata as soon as possible to facilitate collaboration and integration of work among DCERP researchers and MCBCL.

DCERP researchers are responsible for the quality and correctness of data submitted to MARDIS and should interact with the DMM to ensure that

- Data comply with MARDIS standards and contain metadata that conform to the policies developed for the DCERP DIMS and MARDIS,
- Data are uploaded into MARDIS using the approved format and appropriate EDD templates,
- Data subject to revision are updated promptly in MARDIS and revisions are thoroughly documented, and
- Questions and concerns related to submitted data or metadata are promptly resolved.

It is essential that DCERP researchers only upload final quality assured/quality controlled data into MARDIS. In most cases, the raw data should be uploaded; however, the researchers should strive to upload data that are usable to other researchers and ultimately MCBCL. Each data set is addressed on a case-by-case basis in coordination with the DMM to determine appropriate processing prior to archiving in MARDIS and how to best identify that data in MARDIS. Where applicable, standard operating procedures and the methods listed in the metadata must indicate what processing/calculations were performed on the data before they were uploaded into MARDIS.

2.3 Responsibilities of the Data Users

Although SERDP recognizes the legitimate rights of data originators and collaborating DCERP researchers regarding the first use of the data they collect, SERDP encourages data sharing with the scientific community at large and with other stakeholders.

All data users will abide by the terms and policies outlined in this DCERP Data Policy, must follow the Data Access/Release guidelines outlined in Section 3.0, and agree to the Data Use Agreement in Section 4.0. These terms and guidelines include, but are not limited to, working in cooperation with the DCERP researchers, properly citing the DCERP data used, agreeing to the terms of acceptable use, and understanding and agreeing that DCERP data are provided for use solely by the approved data requestor. Any redistribution of the DCERP data or metadata to other unauthorized parties is strictly prohibited.

Access to DCERP data may be subject to registration to enable the DMM to track usage, evaluate the data's impact in the scientific community, and confirm the data user's agreement to the terms of acceptable use. Once registered, approved data users will be allowed access to DCERP data.

The following information will be required for registration to access MARDIS and may also be required directly or by proxy prior to transferring any data to a data requestor via other methods:

- Name of the data requestor
- Affiliation of the data requestor
- E-mail address of the data requestor
- Complete contact information (i.e., street address, city, state, zip code, and telephone)
- Acceptance of the Data Use Agreement, as applicable
- A Statement of Intended Use that complies with the terms and policies outlined in this document (such statements may be submitted explicitly or made implicitly via the MARDIS interface).

3.0 Data Access/Release

To ensure data integrity, DCERP data should be acquired directly from MARDIS and not from other sources that may alter the data or may not include the latest updates and corrections. Once data are acquired from MARDIS, they can then be released by the DMM or by the individual DCERP researcher who collected the data per the terms and policies outlined in this document.

It is important to note that no external release or use of data can occur without MCBCL's approval.

3.1 Data Users

The *DCERP MARDIS Access Policy* created by SERDP (2009) establishes the specific types of data users, which are identified in this section, and the policies for obtaining access to DCERP research and monitoring data for each type of data user. The six primary data users are defined as follows:

1. RTI DCERP Team/DCERP Research Team (to be identified by RTI International)
2. SERDP Management Team (to be identified by the SERDP Executive Director)
3. MCBCL personnel (to be identified by MCBCL)
4. Non-DCERP SERDP/Environmental Security Technology Certification Program (ESTCP) researchers (to be identified by the SERDP Executive Director)
5. Regional Coordinating Committee (RCC; to be identified by the SERDP Sustainable Infrastructure Program Manager)
6. Public individuals.

3.2 Data Types and Availability

3.2.1 Data

SERDP identifies two specific types of DCERP data: monitoring data and research data. These two different types of data should be available for access to data users within the following time frames:

- **Monitoring Data**—DCERP monitoring data, which are identified in the *DCERP Baseline Monitoring Plan* (RTI, 2007a), will be available in MARDIS within 6 months of collection. Data sets requiring lengthy analytical and/or processing procedures may require more time to ensure the data quality prior to uploading; these data sets will be made available when they are completed.
- **Research Data**—DCERP research data, which are identified in the *DCERP Research Plan* (RTI, 2007b), should be available in MARDIS within 2 years of the data collection date to allow time for the DCERP researchers to perform analysis, QA/QC, and publish the final results.

3.2.2 Metadata

Metadata provide supporting information about monitoring and research data that include, but are not limited to, a description of the location where the data were collected, the field and laboratory methods used to collect and analyze the data, and the spatial and temporal frequency of the data. In MARDIS, metadata fields have been combined with the actual sampling data fields; therefore, DCERP metadata are not a separate element, table, or document, but instead they are a part of each data record.

- **Monitoring Metadata**—A summary of the DCERP monitoring metadata is available through the DCERP public Web site (available at <https://dcerp.rti.org>). The DCERP researcher is responsible for ensuring the accuracy of this information.
- **Research Metadata**—Only the DCERP researcher who collected the data can release the DCERP research metadata. Each DCERP researcher is responsible for responding to all requests for metadata in a timely manner and for informing the DMM Leader, Ms. Danette Boezio (dboezio@rti.org), about all requests for DCERP data so the dissemination of DCERP information can be tracked as appropriate.

All metadata must follow DCERP-recommended standards and contain adequate information as defined by the DMM.

3.3 Data and MARDIS User-Access Privileges

Table 1 describes the different data users and the MARDIS user-access privileges for each user group based on the type of data (monitoring or research data) requested.

Table 1. Data and MARDIS User-Access Privileges for DCERP Research and Monitoring Data (Summarized from SERDP's *DCERP MARDIS Access Policy*)

Data Users	MARDIS Access	Monitoring Data	Research Data
DCERP Team	Yes	The DCERP Team has MARDIS view and download data privileges. Prior to downloading data, the user must agree to the Data Use Agreement (Appendix A). Before using the data, the user must inform the respective DCERP researcher, discuss collaboration, and receive approval from the DCERP researcher.	The DCERP Team has MARDIS view and download data privileges. Prior to downloading data, the user must agree to the Data Use Agreement (Appendix A). Before using the data, the user must inform the respective DCERP researcher, discuss collaboration, and receive approval from the DCERP researcher.
SERDP	Yes	SERDP has MARDIS view data privileges.	SERDP has MARDIS view data privileges.
MCBCL	Yes	MCBCL has MARDIS view and download data privileges. Prior to downloading data, the user must agree to the Data Use Agreement (Appendix A) stating that data will only be used for MCBCL reports. In each report, the user is required to acknowledge that DCERP is the data source.	MCBCL has MARDIS view data privileges. MCBCL staff should contact the respective DCERP researcher who generated the data and consult with that researcher to request data and ensure appropriate interpretation of the data.

Data Users	MARDIS Access	Monitoring Data	Research Data
Non-DCERP SERDP/ESTCP researchers	Yes	Non-DCERP SERDP/ESTCP researchers have MARDIS view and download data privileges. Prior to downloading data, the user must agree to the Data Use Agreement (Appendix A). Before using the data, the user must inform the respective DCERP researcher, discuss collaboration, and receive approval from the DCERP researcher.	Non-DCERP SERDP/ESTCP researchers do not have access to data in MARDIS. The user must contact the respective DCERP researcher to request data, discuss collaboration and the specific use of the research data, and receive approval before using the data.
RCC	No	Requests for data must be approved by the DCERP On-Site Coordinator, MCBCL, and the DCERP Principal Investigator (PI; in consultation with the DCERP researcher who collected the data). The DCERP DMM will make the data available only to approved data requestors and will track all data releases.	RCC does not have access to data.
General public	No	Requests for data must be approved by the DCERP On-Site Coordinator, MCBCL, and the DCERP PI (in consultation with the DCERP researcher who collected the data). The DCERP DMM will make the data available only to approved data requestors and will track all data releases.	General public do not have access to data.

Note: All posters, oral presentations, and publications using DCERP data must be reviewed by MCBCL and the DCERP PI prior to submittal or dissemination to ensure Base security and that all products contain appropriate U.S. Department of Defense disclaimers and acknowledgement statements as required by SERDP (see Sections 4.1.1 and 4.1.2, respectively).

4.0 DCERP Data Use Agreements

Monitoring and research data sets released by DCERP will be accompanied by the Data Use Agreement (Appendix A), which describes the general roles and the obligations and rights enjoyed by each data user regarding the use of the released data sets.

4.1 RTI DCERP Team Use Agreement

Each RTI DCERP Team data user must agree to the following statement prior to accessing and/or downloading of information from MARDIS:

“The information and research and monitoring data are for the exclusive use of the DCERP Team, including the RTI DCERP Team, SERDP, and MCBCL. Distribution and/or release of this information and/or data outside of the DCERP Team are prohibited without the expressed approval from MCBCL and the DCERP Principal Investigator (PI). Although every effort has been made to ensure the accuracy of the information and data, complete accuracy cannot be guaranteed. The data user must be aware of data conditions and ultimately bear responsibility for the appropriate use of the information with respect to possible errors, collection methodology, currency of the data, and other conditions specific to certain data. If you have any questions concerning data access or use policies, please contact the DCERP PI, Dr. Patricia Cunningham, at patc@rti.org.”

By agreeing to this statement, DCERP Team members also agree to all terms in the General Data Use Agreement outlined in Section 4.2. Each DCERP researcher is responsible for assuring that the data are safeguarded from others who have not been approved to access DCERP data.

4.1.1 U.S. Department of Defense Disclaimer

All publications or reports prepared as part of DCERP must conspicuously display the following disclaimer on the cover page or in the front matter of the report:

“Views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official U.S. Department of Defense position or decision unless so designated by other official documentation.”

4.1.2 SERDP Acknowledgment

The following acknowledgement statement must also be included in any report prepared as part of DCERP:

“This research was conducted under the Defense Coastal/Estuarine Research Program (DCERP), funded by the Strategic Environmental Research and Development Program (SERDP).”

DCERP Team members should also recognize and acknowledge, as appropriate, the services provided by MCBCL as the host installation.

4.2 General Data Use Agreement (All Other Users)

The General Data Use Agreement pertains to SERDP, MCBCL, non-DCERP SERDP/ESTCP researchers, RCC, and the general public.

The use of DCERP data has the potential to greatly increase communication, collaboration, and synthesis within and among various disciplines, and thus is fostered, supported, and encouraged by SERDP. By accepting DCERP data, the data user agrees to abide by the terms of the Data Use Agreement. The DCERP Principal Investigator (PI) or individual DCERP researcher has the right to immediately terminate this agreement by written notice if the data user breaches or does not comply with any of the terms outlined in this agreement. The data user may be held responsible for any misuse that is caused or encouraged by his or her failure to abide by the terms of this agreement. In accordance with the Data Use Agreement (Appendix A),

“Permission to use DCERP data is granted to the data user subject to the following terms and conditions:

- *Acceptable use.* Use of the DCERP data is restricted to academic, research, educational, government, or other not-for-profit professional purposes. Distribution and/or release of this information and/or data for other purposes are strictly prohibited.
- *Redistribution.* DCERP data are provided for use only by the data requestor/user. Redistribution of the metadata or data to other unauthorized parties is strictly prohibited.
- *Citation.* The DCERP researcher has first rights of publication. It is considered a matter of professional ethics to acknowledge the work of other researchers; therefore, the data user must properly cite the DCERP data in any publications and/or in the metadata of any derived data products that were produced using DCERP data. A citation should appear in the following general format: *DCERP researcher, year of data collection, title of dataset: program (DCERP), MARDIS (database), and date accessed.*

Christensen, N. 2009. EPA Criteria Pollutants - (Ozone, Sulfur Dioxide, Particulate Matter): DCERP Monitoring and Research Data Information System [Database] [Accessed 6 April 2009]).

- *Collaboration.* DCERP data have been released in the spirit of open scientific collaboration; therefore, data users are strongly encouraged to consider consultation, collaboration, and/or co-authorship with the DCERP researcher who collected the data.
- *Notification.* The data user will notify the DCERP PI and the DCERP On-Site Coordinator (OSC) when any derivative work or publication based on or derived from the DCERP data is being prepared for distribution in posters, oral presentations, or publications. Notification will include an explanation of how the DCERP data were used to produce the derived work. It is important to note that similar to DCERP Team members, all non-DCERP SERDP /ESTCP researchers who use DCERP data in presentations or publications must have these posters, oral presentations, and papers reviewed by the DCERP PI, DCERP OSC, and MCBCL prior to submittal of the information for presentation or publication to ensure Base security and that all products contain appropriate U.S. Department of Defense disclaimers and SERDP acknowledgement statements (see Sections 4.1.1 and 4.1.2, respectively). In addition, the data user will provide the DCERP PI with two reprints of any publications resulting from the use of the DCERP data and will provide copies, or online access to, any derived digital products.
- *Data liability.* Although substantial efforts are made to ensure the accuracy of data and documentation contained in MARDIS, complete accuracy of data and metadata cannot be guaranteed; all data and metadata are made available “as is.” The data user agrees not to hold the RTI DCERP Team or the individual DCERP researcher liable or responsible for any loss, damage, claim, cost, or expense as a result of DCERP data contents or their use or interpretation. The data user must be aware of data conditions and ultimately bear responsibility for the appropriate use of the information.”

4.3 MCBCL and MCBCL Contractors Data Use Agreement

In consultation with DCERP researchers, MCBCL personnel may release data for use by MCBCL contractors. However, a statement of agreement must accompany the data, and the receipt of any data by contractors implies acceptance of the terms of use, to include all terms and agreements in the General Data Use Agreement previously outlined in Section 4.2. In addition, it is understood that

- DCERP data received by MCBCL staff or MCBCL contractors will be used only for the preparation of documents for MCBCL,
- The DCERP researcher who collected the data has first rights of publication, and
- MCBCL staff and MCBCL contractors will give appropriate credit to the DCERP researcher in the documents they prepare for MCBCL.

5.0 References

RTI (RTI International). 2007a. *DCERP Baseline Monitoring Plan*. Prepared for Strategic Environmental Research and Development Program (SERDP), Arlington, VA. Available at <https://dcerp.rti.org/DCERPPublicSite/PublicDocuments>.

RTI. 2007b. *DCERP Research Plan*. Prepared for SERDP, Arlington, VA. Available at <https://dcerp.rti.org/DCERPPublicSite/PublicDocuments>.

RTI. 2007c. *DCERP Strategic Plan*. Prepared for SERDP, Arlington, VA. Available at <https://dcerp.rti.org/DCERPPublicSite/PublicDocuments>.

SERDP (Strategic Environmental Research and Development Program). 2009. *DCERP MARDIS Access Policy*. Arlington, VA.

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Appendix B
Data Use Agreement

(To accompany all data transfers)

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DCERP Data Use Agreement

Version 1.0: November 2009

By accepting DCERP data, the data user agrees to abide by the terms of the Data Use Agreement. The DCERP Principal Investigator (PI) or individual DCERP researcher has the right to immediately terminate this agreement by written notice if the data user breaches or does not comply with any of the terms outlined in this agreement. The data user may be held responsible for any misuse that is caused or encouraged by his or her failure to abide by the terms of this agreement.

The information and research and monitoring data are for the exclusive use of the DCERP Team, including the RTI DCERP Team, SERDP, and MCBCL. Distribution and/or release of this information and/or data outside of the DCERP Team are prohibited without the expressed approval from MCBCL and the DCERP PI. Although every effort has been made to ensure the accuracy of the information and data, complete accuracy cannot be guaranteed. The data user must be aware of data conditions and ultimately bear responsibility for the appropriate use of the information with respect to possible errors, collection methodology, currency of the data, and other conditions specific to certain data. If you have any questions concerning data access or use policies, please contact the DCERP PI, Dr. Patricia Cunningham, at patc@rti.org.

Permission to use DCERP data is granted to the data user subject to the following terms and conditions:

- *Acceptable use.* Use of the DCERP data is restricted to academic, research, educational, government, or other not-for-profit professional purposes. Distribution and/or release of this information and/or data for other purposes are strictly prohibited.
- *Redistribution.* DCERP data are provided for use only by the data requestor/user. Redistribution of the metadata or data to other unauthorized parties is strictly prohibited.
- *Citation.* The DCERP researcher has first rights of publication. It is considered a matter of professional ethics to acknowledge the work of other researchers; therefore, the data user must properly cite the DCERP data in any publications and/or in the metadata of any derived data products that were produced using the DCERP data. A citation should appear in the following general format: *DCERP researcher, year of data collection, title of dataset: program (DCERP), MARDIS (database), and date accessed.*

Christensen, N. 2009. EPA Criteria Pollutants - (Ozone, Sulfur Dioxide, Particulate Matter): DCERP Monitoring and Research Data Information System [Database] [Accessed 6 April 2009]).
- *Collaboration.* DCERP data have been released in the spirit of open scientific collaboration; therefore, data users are strongly encouraged to consider consultation, collaboration, and/or co-authorship with the DCERP researcher who collected the data.
- *Notification.* The data user will notify the DCERP PI and the DCERP On-Site Coordinator (OSC) when any derivative work or publication, based on or derived from the DCERP data, is being prepared for distribution in posters, oral presentations, or publications. Notification will include an explanation of how the DCERP data were used to produce the derived work. It is important to note that similar to DCERP Team members, all non-DCERP SERDP/ESTCP researchers who use DCERP data in presentations or publications must have these posters, oral presentations, and papers reviewed by the DCERP PI, DCERP OSC, and MCBCL prior to submittal of the information for presentation or publication to ensure Base security and that all products contain appropriate U.S. Department of Defense disclaimers and SERDP acknowledgement statements. In addition, the data user will provide the DCERP PI with two reprints of any publications resulting from the use of the DCERP data and will provide copies, or online access to, any derived digital products.
- *Data liability.* Although substantial efforts are made to ensure the accuracy of data and documentation contained in MARDIS, complete accuracy of data and metadata cannot be

guaranteed; all data and metadata are made available “as is.” The data user agrees not to hold the RTI DCERP Team or the individual DCERP researcher liable or responsible for any loss, damage, claim, cost, or expense as a result of DCERP data contents or their use or interpretation. The data user must be aware of data conditions and ultimately bear responsibility for the appropriate use of the information.

For MCBCL and MCBCL contractors, in addition to all terms and conditions in the General Data Use Agreement previously outlined, it is understood that

- DCERP data received by MCBCL staff or MCBCL contractors will be used only for the preparation of documents for MCBCL,
- The DCERP researcher who collected the data has first rights of publication, and
- MCBCL staff and MCBCL contractors will give appropriate credit to the DCERP researcher in the documents they prepare for MCBCL.